

***Cypripedium montanum* Douglas ex Lindley  
(mountain lady's slipper):  
A Technical Conservation Assessment**



**Prepared for the USDA Forest Service,  
Rocky Mountain Region,  
Species Conservation Project**

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## COVER PHOTO CREDIT

*Cypripedium montanum* (mountain lady's slipper). Photograph by the author.

# SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *CYPRIPEDIUM MONTANUM*

## *Status*

*Cypripedium montanum* Douglas ex Lindley (mountain lady's slipper) is an orchid species endemic to western North America and widely distributed in the montane forests of seven western states and Canada. In Region 2, *C. montanum* is limited to the eastern flank of the Bighorn Mountains in Johnson and Sheridan counties, Wyoming, with six documented occurrences comprising fewer than 2,500 individuals.

The NatureServe Global rank for *Cypripedium montanum* is G4 (apparently secure). The Wyoming Natural Diversity Database State rank for this species is S1 (critically imperiled). These global and subnational ranks have no regulatory status. *Cypripedium montanum* has no federal status, but the USDA Forest Service Region 2 Regional Forester has designated it a sensitive species. *Cypripedium montanum* is not on the USDI Bureau of Land Management Wyoming State Director's sensitive species or rare plant list.

## *Primary Threats*

The primary potential threats to *Cypripedium montanum* are large disturbances that can destroy all or a portion of breeding populations. These may be natural or human-related disturbances such as stand-replacing wildfires, or mechanized logging or recreational activities. Conversely, fire suppression that allows the overstory canopy to close and thus increases competition for light, nutrients, and water may threaten the long-term persistence of the species. Progressive soil erosion may be a threat to this shallow-rooted species. Any disturbance that destroys the root crown will destroy the plant. *Cypripedium montanum* may be more vulnerable when flowering due to its beauty and its proximity to access roads and trails in popular recreational areas. Severe grazing may be a direct and indirect threat to *C. montanum* individuals growing in grazing allotments. The species' limited distribution in small populations in Region 2 on the periphery of its range increases its vulnerability to habitat alteration resulting from management activities or loss of plants through other activities such as trampling or collecting.

## *Primary Conservation Elements, Management Implications and Considerations*

*Cypripedium montanum* is a wide-ranging species in the montane western United States. However, only six occurrences are documented in Region 2, and all of these are within a limited area on the eastern flank of the Bighorn Mountains. Four occurrences are located on the Bighorn National Forest. With so few occurrences, losing any of them has critical implications for conservation management.

The degree to which *Cypripedium montanum*, a long-lived perennial orchid, may be adversely impacted depends largely on the nature of the disturbance and how it affects elements of the species' life cycle. Evidence indicates that *C. montanum* is particularly vulnerable to the consequences of environmental or human-related habitat alterations when populations are small and have infrequent recruitment and low reproductive success. Lack of monitoring and inventory data hampers managing the few occurrences in Region 2. Documenting population changes on the landscape through inventorying and monitoring populations and habitat is an essential first step in evaluating whether current populations are stable, increasing, or decreasing. If population trends reveal a steady decline or contraction of range over several years, it may indicate an underlying fundamental ecological problem.

There is no documentation of how the abundance of *Cypripedium montanum* and its range have changed over the last century. Therefore, given the limited number of occurrences, low number of individuals, and narrow distribution of this species within the region, developing an information base in coordination with the private sector is essential for conservation management to be effective. Stabilizing populations on the periphery of the species' range has implications for the conservation of the genetic diversity not only of the species, but also the *Cypripedium* genus, which is among the most threatened of all orchid genera.

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## INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Cypripedium montanum* Douglas ex Lindley (mountain lady's slipper) is the focus of an assessment because this species is rare on National Forest System land in Region 2 and because it is a Region 2 sensitive species. A sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance and/or in habitat capability that would reduce its distribution (FSM 2670.5 (19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Cypripedium montanum* throughout its range in Region 2. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production (Blankenship et al. 2001).

### ***Goal of the Assessment***

Conservation assessments produced for the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e. management implications). Furthermore, it cites management recommendations proposed elsewhere and examines the success of recommendations that have been implemented.

### ***Scope of the Assessment***

This assessment examines the biology, ecology, conservation status, and management of *Cypripedium montanum*, with specific reference to the geographic and ecological characteristics of USFS Region 2.

Literature documenting the biology and ecology of this species may be based on studies of other species of *Cypripedium* as well as on studies of *C. montanum* outside of Region 2. This literature is cited where content is pertinent and applicable to the populations in the northern and central Rocky Mountains. The context for the assessment emphasizes current conditions. Evolutionary considerations are addressed only as they apply to the current environment.

Numerous refereed (peer reviewed) and non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed to produce this report. The assessment emphasizes the refereed literature because this is the accepted standard in science. However, non-refereed literature was used if that information was not documented elsewhere. Reports or non-refereed publications on rare plants can be 'works-in-progress' or based on isolated observations. For example, the population for which demographic data were presented in this document may require additional years of monitoring before long-term inferences are reliable. Nevertheless, after a few years of monitoring, year-to-year observations are useful. Unpublished data (e.g., Natural Heritage Program and herbarium records) were extremely useful and provided salient information for estimating geographic distribution, habitat, and population sizes. Occurrence data were compiled from the Wyoming Natural Diversity Database (2005).

### ***Treatment of Uncertainty***

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are incomplete and our observations limited, science includes approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct critical experiments in the ecological sciences. Often, a systems approach must be relied on to guide the understanding of ecological relations. While an approach based on testing hypotheses and building predictive models is widely held as the primary means to building a scientific body of knowledge, observations are necessary to understanding natural phenomena at different scales. Sometimes ecological approaches begin with data on hand derived from inventories, categories, and counting (Allen and Hoekstra 1992). In addition, to describe and understand complex human/natural resource systems, a more realistic application of

science may depend upon participatory approaches for acquisition of experientially acquired group knowledge (Turner 1995).

### ***Publication of the Assessment on the World Wide Web***

To facilitate use of species assessments in the Species Conservation Project, this document is published in PDF format on the Region 2 World Wide Web site (<http://www.fs.fed.us/r2/projects/scp/assessments/index.shtml>). Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it facilitates revision of the assessment, which will be accomplished based on guidelines established by Region 2.

### ***Peer Review of the Assessment***

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the Web. This assessment for *Cypripedium montanum* was reviewed through a process administered by the Center for Plant Conservation, employing two recognized experts on this or related taxa.

## **MANAGEMENT STATUS AND NATURAL HISTORY**

### ***Management Status***

Within Region 2, *Cypripedium montanum* occurs only in Wyoming. The six documented occurrences are all in Sheridan or Johnson counties. Four occurrences are on the Bighorn National Forest, one is historic on private land, and one is on land managed by the Buffalo Field Office of the Bureau of Land Management (BLM).

*Cypripedium montanum* is a sensitive species in Region 2. The species is not listed as threatened or endangered under the federal Endangered Species Act, nor is it on the BLM Wyoming State Director's sensitive species list (USDI Bureau of Land Management 2002). The NatureServe global rank for *C. montanum* is apparently secure (G4) (NatureServe 2005). The Wyoming Natural Diversity Database (WYNDD) state rank for *C. montanum* is critically imperiled (S1).

*Cypripedium montanum* occurs on National Forest lands in other USFS regions, but is considered a sensitive species only in the Pacific Southwest Region (Region 5; USDA Forest Service 2000). State

conservation ranks in states outside of Region 2 include critically imperiled (S1) in Alaska, apparently secure (S4) in California, vulnerable to apparently secure (S3S4) in Oregon, and not ranked (SNR) in Idaho, Montana, and Washington. See the Colorado Heritage Network Program website ([www.cnhp.colostate.edu](http://www.cnhp.colostate.edu)) for more information on the National Heritage Network and their conservation ranking system.

### ***Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies***

*Cypripedium montanum* has no federal status other than as a sensitive species in USFS Region 2. *Cypripedium montanum*'s status as sensitive applies only to the four occurrences on the Bighorn National Forest. Sensitive species status provides some protection on National Forest System land. Some additional protection may be afforded by the National Forest Management Act and USFS policy that requires National Forest System land be managed to maintain viable populations of all native plant and animal species (FSM 2670.5.22). No other laws or regulations confer protection to this species on private, state, or other federal lands.

USFS management objectives for sensitive species are designed to ensure continued viability throughout their range on National Forest System lands and to ensure that they do not become threatened or endangered because of actions of the USFS (FSM 2670.22). Existing policy in Region 2 calls for avoiding or minimizing impacts to species whose viability has been identified as a concern, or if impacts cannot be avoided, analyzing the significance of potentially adverse effects on populations or habitat within the area of concern and on the species as a whole (FSM 2670.32).

Because of a shortage of funds and personnel, the only active protection of a USFS sensitive species occurs when management actions are proposed within known or potential habitat. Management projects such as fuels reduction implemented under the revised Bighorn National Forest Management Plan (USDA Forest Service 2005) require analysis of effects of implementation for sensitive species. *Cypripedium montanum* would also be evaluated at the project level. For example, the Tongue Ranger District of the Bighorn National Forest prepared an environmental assessment (EA) for fuels reduction treatments including thinning, piling and prescribed burning (USDA Forest Service 2003d). The areas proposed for fuels treatment

included the largest known *C. montanum* occurrence on the Bighorn National Forest. The EA addressed *C. montanum* and recommended both quantitative and qualitative monitoring of *C. montanum* in plots within the treatment area. Thus, because of a proposed forest management action, monitoring was effected for occurrence (WY-1 in **Table 1**).

There has been no documented case in which an occurrence of *Cypripedium montanum* was extirpated due to human activity or the failure to enforce any existing regulations in Region 2. This does not imply that legal protection is necessarily adequate for occurrences subjected to future land use or extractive activities. Other than controls by the Convention on International Trade in Endangered Species that pertain only to international trade (CITES 2005), regulatory protections that apply to this species only affect occurrences on National Forest System land.

## ***Biology and Ecology***

### Classification and description

#### *Systematics, synonymy, and history*

*Cypripedium montanum* Douglas ex Lindley is a member of the subfamily Cypripedioideae in the Orchidaceae. The Orchidaceae is in the class Liliopsida (monocot), subclass Liliidae, order Orchidales (Hickey and King 1981, USDA Natural Resources Conservation Service 2006). Dressler (1993) divided the Orchidaceae into five subfamilies, including the Cypripedioideae. This subfamily shares the characteristics of having two lateral fertile anthers, a sterile median anther or staminode, a deeply sacchate labellum, and single-grained sticky pollen with thin-walled exines. The Cypripedioideae, the slipper orchids, is composed of four genera: *Cypripedium*, *Selenipedium*, *Phragmipedium*, and *Paphiopedilum*. All slipper orchids were once included in the genus *Cypripedium*, originally named by Linnaeus, but the diversity of species was gradually recognized. Of the four genera now included in the subfamily Cypripedioideae, only *Cypripedium* occurs in the United States. Rolfe (1896) listed 28 *Cypripedium* species, of which 11 were restricted to the western hemisphere, 14 to eastern Asia, while three were widespread (Cribb 1997). The genus now is thought to contain about 50 species widespread in boreal, temperate, and tropical regions of the European, Asian, and North American continents (Correll 1950). There are more than 30 species distributed in the

northern hemisphere and about 11 species in the United States (Coleman 1995).

The Integrated Taxonomic Information System (2006) lists *Cypripedium montanum* as the accepted binomial for this taxon. No synonyms are listed. According to Sheviak (1992), *C. montanum* is one of four North American members of the circumboreal *C. calceolus* complex. Other North American species include *C. candidum*, *C. kentuckiense*, and *C. parviflorum* (formerly considered *C. calceolus*), the latter with three varieties, *parviflorum*, *pubescens*, and *makasin*. Cribb (1997) does not recognize Sheviak's var. *makasin*; rather, the generally accepted name is *C. pubescens* Willd. var. *makasin* Farw. (USDA Natural Resources Conservation Service 2004, 2006). Sheviak (1992) restricts *C. calceolus* to Eurasian members of the complex.

In sixteenth century Europe, the slipper orchid was described and botanically illustrated with labels in German, "Papen schoen" or "Marienschuh," or in Latin "Calceolus Marianus," a reference to "shoe of the virgin Mary." The first documentation of the name *Cypripedium* was by Linnaeus in 1737 in his *Flora Lapponica* (Cribb 1997). The genus name *Cypripedium* retained the reference to a shoe or slipper in classical Greek literature derived from the Greek words "Cypris" an early reference in Greek myth to the island of Aphrodite, and "pedilon" Greek for sandal. Possibly the earliest reference to a North American *Cypripedium* species was in 1635 by Cornut, who listed *Calceolus marianus canadensis* in reference to *Cypripedium reginae* (Cribb 1997).

#### *History of knowledge*

The early nineteenth century explorers Lewis and Clark observed an orchid that Clark described as a "lady's slipper or moccasin flower" near Traveler's Rest in Montana and collected a specimen on the Weippe Prairie in Clearwater County, Idaho on June 14, 1806 (**Figure 1**). In 1828, David Douglas collected an orchid specimen in the Blue Mountains of Washington and named it *Cypripedium montanum* (Douglas 1914). John Lindley (1840) published a description of this specimen. Watson published the name *C. occidentale* in 1876 based on several collections from western North America. Subsequent examination of the material confirmed that *C. occidentale* was conspecific with *C. montanum* (Cribb 1997).

**Table 1. *Cypripedium montanum* occurrences in USDA Forest Service Region 2 (Wyoming) with approximate location, abundance, and habitat (Wyoming Natural Diversity Database 2005).**

| Occurrence no. -<br>Site name                  | Landowner   | County               | Elevation<br>(ft.) | Estimated<br>abundance   | First<br>observed | Last<br>observed | Extent<br>(ha) | General habitat description   | Associated species  |
|--|---|----------------------|--------------------|--|-------------------|------------------|----------------|---|---|
| WY-1<br>Story                                  | Bighorn National<br>Forest<br>Tongue Ranger<br>District   | Johnson,<br>Sheridan | 5,400 to<br>6,600  | 2,000 individuals<br>distributed in<br>three habitats                          | 1928              | 2004             | 97             | (1) Moist, open to shaded stream sides and<br>boggy areas among shrubs in shady valley<br>bottoms on sandy-organic loam<br>(2) At the edge of <i>Pinus ponderosa</i><br><i>/Pseudotsuga menziesii</i> / <i>P. contorta</i> and<br>edges of <i>Acer glabrum</i> and <i>Crataegus</i><br><i>douglasii</i> thickets, and under pole and<br>larger sized <i>Populus tremuloides</i> stands on<br>fairly level areas at mid slope. Forb cover<br>often close to 100%. Often on north-facing<br>slopes on moderately moist soils, but can<br>also occur on south slopes on drier soils<br>(3) Open south slopes with scattered <i>Pinus</i><br><i>ponderosa</i> | (1) <i>Fragaria virginiana</i> ,<br><i>Geranium richardsonii</i> ,<br><i>Thalictrum venulosum</i> ,<br><i>Balsamorhiza sagittata</i> ,<br><i>Delphinium bicolor</i><br>(2) <i>Pseudotsuga menziesii</i> , <i>Pinus</i><br><i>ponderosa</i> , <i>Picea engelmannii</i> ,<br><i>Geranium</i> sp., <i>Athyrium</i> sp.,<br><i>Toxicodendron rydbergii</i> , <i>Cornus</i><br>spp., <i>Equisetum</i> spp., <i>Rosa</i> sp.,<br><i>Actaea rubra</i><br>(3) <i>Anemone</i> sp., <i>Lupinus</i> sp.,<br><i>Apocynum</i> sp., <i>Balsamorhiza</i><br><i>sagittata</i> , <i>Monarda fistulosa</i> ,<br><i>Galium</i> sp., <i>Fragaria virginiana</i> ,<br><i>Pinus ponderosa</i> |
| WY-2<br>Middle Clear<br>Creek<br>(Hunter Mesa) | Bighorn National<br>Forest<br>Powder River<br>Ranger District<br>(old)                          | Johnson              | 8,000              | Not available<br>(historical<br>specimen)                                      | 1900              | 1900             | NA             | Thought to be between the headwaters of<br>Clear Creek and Crazy Woman River  | Not reported  |
| WY-3<br>Wolf Creek                             | Bighorn National<br>Forest<br>Tongue Ranger<br>District   | Sheridan             | 5,000 to<br>5,400  | Every year tops<br>are browsed<br>off plants,<br>preventing seed<br>production | 1986              | 1992             | NA             | Riparian community in shade of shrubs<br>along creek on limestone   | Not reported except for<br><i>Cypripedium pubescens</i> var.<br><i>pubescens</i>  |
| WY-4<br>Little Goose<br>Creek                  | Bighorn National<br>Forest<br>Tongue Ranger<br>District; Private<br>- The Nature<br>Conservancy | Sheridan             | 5,400 to<br>5,520  | 250 in two<br>colonies, 150<br>flowering plants<br>(2004 survey)               | 1999              | 2004             | 1 to 2         | <i>Pseudotsuga menziesii</i> / <i>Populus</i><br><i>tremuloides</i> / <i>Spiraea betulifolia</i> community<br>on open to partially shaded north slopes<br>of 10-20%. Located in undergrowth of<br>moist aspen community. Much unsurveyed<br>potential habitat in vicinity   | <i>Pseudotsuga menziesii</i> , <i>Populus</i><br>sp., <i>Ribes</i> sp., <i>Geranium</i> sp.,<br><i>Salix</i> sp., <i>Rosa</i> sp., <i>Sullivantia</i><br><i>hapemanii</i>   |
| WY-5<br>Bear Gulch                             | Private   | Johnson              | 5,500              | Two flowering<br>plants observed<br>in 1999                                    | 1999              | 1999             | NA             | Aspen woods on shady flats; moist alluvial<br>soils   | <i>Populus tremuloides</i> , <i>Viburnum</i><br><i>lentago</i>  |

**Table 1 (concluded).**

| Occurrence no. -<br>Site name | Landowner  | County   | Elevation<br>(ft.) | Estimated<br>abundance   | First<br>observed | Last<br>observed | Extent<br>(ha) | General habitat description   | Associated species  |
|-------------------------------|--|----------|--------------------|--|-------------------|------------------|----------------|---|---|
| WY-6<br>Red Grade             | Bureau of Land<br>Management<br>Buffalo Field<br>Office; Private | Sheridan | 6,730 to<br>6,900  | 150, all<br>flowering. Non-<br>flowering plants<br>not counted | 2004              | 2004             | 2              | East-facing slope with forested area<br>dominated by <i>Pinus contorta</i> , <i>Populus</i><br>spp., and <i>Pseudotsuga menziesii</i> bisected<br>by a road. Site is immediately adjacent to<br>user-created camping site and cattle trail<br>next to the road. Gravelly silt loam soil | <i>Pinus contorta</i> , <i>Pseudotsuga</i><br><i>menziesii</i> , <i>Populus</i> sp.,<br><i>Maianthemum racemosum</i> ,<br><i>Chimaphila umbellata</i> ,<br><i>Platanthera</i> spp., <i>Geranium</i><br><i>viscosissimum</i> , <i>Corallorhiza</i><br><i>maculata</i> , <i>Vaccinium scoparium</i> ,<br><i>Spiraea</i> sp., <i>Arnica</i> sp.,<br><i>Antennaria racemosa</i> , <i>Viola</i> sp.,<br><i>Goodyera oblongifolia</i> |



**Figure 1.** Photograph of a specimen of *Cyripedium montanum* collected in Idaho County in 1896 near the site where Meriwether Lewis and William Clark first reported seeing the orchid. Image courtesy of the U.S. National Herbarium, Smithsonian Institution, Washington, D.C., used with permission.

### Species description

*Cypripedium montanum* stems are between 2 and 7 dm (8 and 28 inches) tall, glandular-pubescent, and leafy throughout, with one or more stems growing from a short, stout rhizome. The mature plants have five to seven leaves that are broadly elliptic to ovate-elliptic, alternating up the erect stem (**Figure 2**). The glandular pubescent stem is covered at the base with sheaths. The leaves are 5 to 15 cm (2 to 6 inches) long, up to 7 cm (2.3 inches) broad, somewhat glandular-pubescent, sessile and usually sheathing. The inflorescence may have one to three flowers that are each subtended and usually exceeded by an erect leaf-like bract. Sepals and petals range from a light to rather deep brownish-purple. The dorsal sepal is 3 to 6 cm (1 to 2.4 inches) long and ovate-lanceolate (Coleman 1995, Cribb 1997); the synsepal is elliptic, lanceolate and bidentate, and fused except for the slender terminal tooth-like lobes. The petals are 4.5 to 7 cm (1.8 to 2.4 inches) long, slightly longer than the sepals, narrowly to broadly lanceolate, and usually more or less twisted and wavy. The labellum is obovoid and strongly pouched, 2 to 3 cm (0.8 to 1 inch) long, dull white to purplish-tinged, usually purplish-veined and inrolled around the orifice. The column is about 1 cm (0.4 inch) long. The staminode is up to 12 mm (0.5 inch) long, glabrous and yellow with red spotting (**Figure 3**), and only rarely auriculate (lobed) at the base (Hitchcock et al. 1969). The orchid is diandrous with each of the two fertile stamens on either side of the column. The pedicel and ovary are 2 to 3.6 cm (0.8 to 1.4 inches) long, densely glandular, and pubescent (Cribb 1997).

Detailed technical descriptions with line drawings appear in Abrams (1940), Correll (1950), Munz (1959), Peck (1961), Hitchcock et al. (1969), Luer (1969), and Hickman (1993). Descriptions and photographs are found in Coleman (1995), and a description with color photographs and line drawings is located in Cribb (1997). Cribb (1997) and Doherty (1997) have recent summaries of what is known about the genus *Cypripedium*. Their reviews cover morphology, life history, cytology, phylogenetic relationships, biogeography, and ecology including mycorrhizal associations, uses, culture and propagation, artificial hybridization, and taxonomy.

*Cypripedium montanum* and *C. pubescens* var. *pubescens* (*C. parviflorum* var. *pubescens* or *C. calceolus* var. *pubescens*) may be sympatric in Wyoming and could hybridize (Sheviak 1992). *Cypripedium pubescens* var. *pubescens* has a large yellow labellum

or pouch whereas the labellum of *C. montanum* is white, smaller, and shows purple striations or veins. Sheviak (1992) has reported that because in certain instances their proximity has produced conditions that may have allowed hybridization, thus, obscuring morphological differences among them. In addition, *Cypripedium* species can also show morphological differences among individuals and populations having petals and sepals that may range from deep purple to light brown and variations in size of flower and plant. However, no evidence of morphological variants or hybridization has been reported for Wyoming populations of *C. montanum*. The flowering traits of *C. montanum*, *C. pubescens* var. *pubescens*, and *C. parviflorum* can overlap and particularly if there are morphological variants within each species (**Table 2**). Variants of *C. montanum* have been described: a white-petaled form (*praetertinctum*) Sheviak (1990), and a crimson edge-lipped form (*welchii*) Brown (1995).

### Distribution and abundance

The global range of *Cypripedium montanum* spans seven western states and three Canadian provinces. Wyoming occurrences are at the southeastern edge of the species' range. The range of *C. montanum* in 1969 extended from southern Alaska, British Columbia, and western Alberta south to Montana, Idaho, Wyoming, and Santa Cruz County in northern California (Hitchcock et al. 1969). The range map (**Figure 4**) may not represent recent discontinuities within its range. For example, there are no documented occurrences in Montana counties directly north of Bighorn and Sheridan counties, and records for occurrences in counties further north in the Judith or Little Belt mountains are historic (more than 50 years old). This species apparently is no longer extant on Vancouver Island (Clark 1976), nor is it known from the Olympic Peninsula (Hitchcock et al. 1969). In Oregon, it has been documented in the following counties: Baker, Crook, Deschutes, Douglas, Grant, Hood River, Jackson, Jefferson, Josephine, Klamath, Lake, Lane, Marion, Umatilla, Union, Wallowa, Wasco, and Wheeler (USDA Forest Service and USDI Bureau of Land Management 1994a). In California, *C. montanum* occurs in Del Norte, Humboldt, Mendocino, Modoc, Mariposa, Plumas, San Francisco, San Mateo, Sierra, Siskiyou, Tehama, Trinity, and Tuolumne counties (CalFlora Database 1997). The Washington Natural Heritage Program has 132 sighting forms on file dated 1980 or later, but has not tracked the species since 1982 (Caplow 2002). In Washington, it is documented in Asotin, Columbia, Chelan, Ferry, Douglas, Garfield, Klickitat, Kittitas,



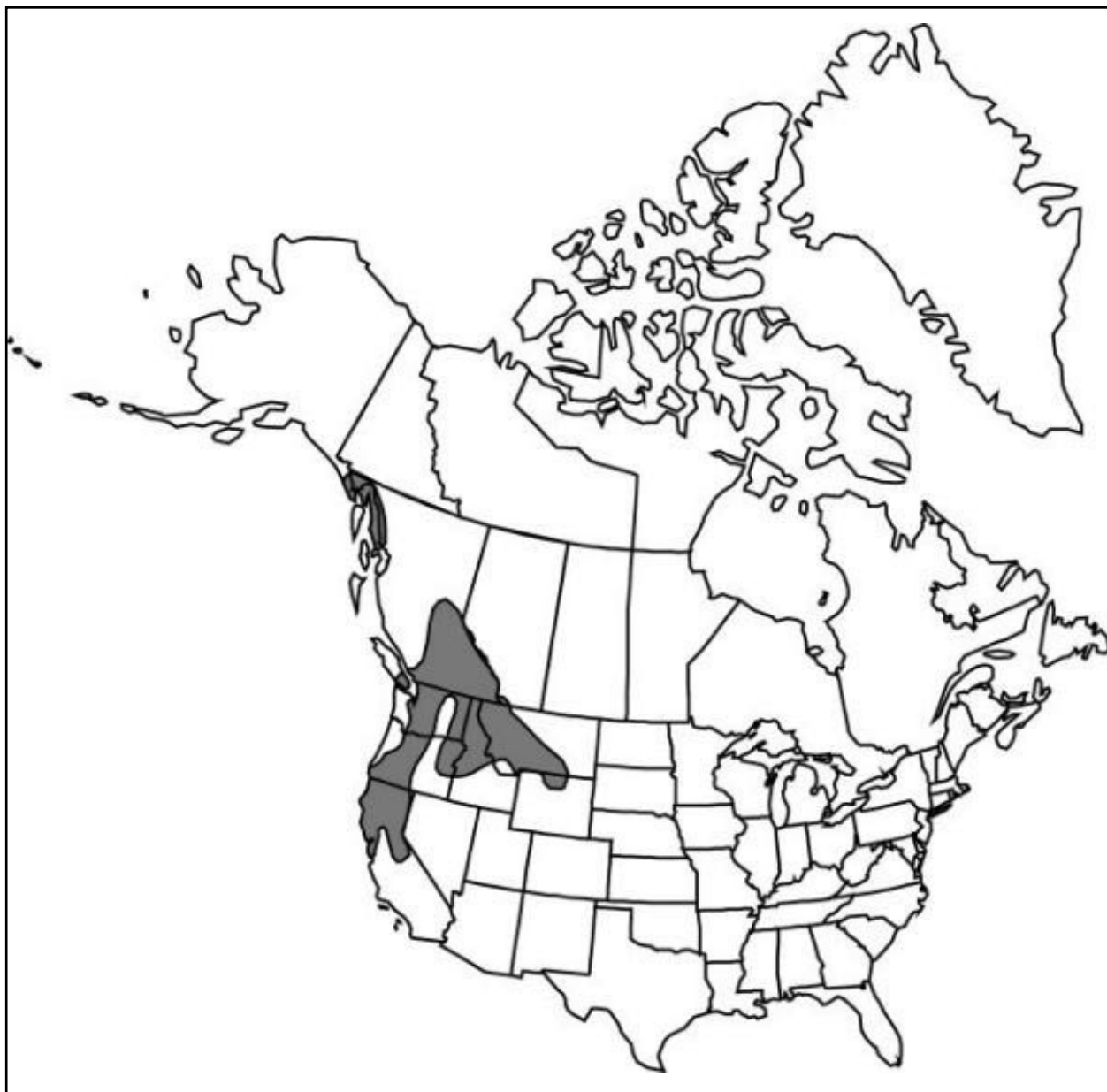
**Figure 2.** Illustration of *Cypripedium montanum*. Botanical print reproduced with permission from the collections of the Library of Congress.



**Figure 3.** Close-up photograph of *Cypripedium montanum* flower showing the column, yellow staminode and white labellum (lip) with purple striations. Photograph by the author.

**Table 2.** Distinguishing characteristics among *Cypripedium montanum*, *C. pubescens* var. *pubescens*, and *C. parviflorum*.

| Taxon   | Inflorescence        | Sepals/ petals coloration                            | Dorsal sepal length (cm) | Lip color & length (cm)                                  | Staminode color & length (mm)        | Pedicel/ ovary length (cm) |
|---|----------------------|--|--------------------------|--|--------------------------------------|----------------------------|
| <i>C. montanum</i><br>Dougl. ex Lindl.<br>Mountain lady's slipper                       | glandular- pubescent | maroon-brown   | 3.0 to 6.5               | white with purple veins<br>2 to 3                        | yellow with red spotting<br>8 to 12  | 2.0 to 3.6                 |
| <i>C. pubescens</i><br>Willd. var.<br><i>pubescens</i><br>Greater yellow lady's slipper | glandular- hairy     | yellow or greenish streaked with rusty to dull brown | 2.5 to 8.5               | yellow with magenta spots and streaks within<br>2 to 5.2 | yellow with red spotting<br>10 to 12 | 2.0 to 3.2                 |
| <i>C. parviflorum</i><br>Salisb.<br>Lesser yellow lady's slipper                        | glandular- hairy     | madder, purple to maroon                             | 2.0 to 4.0               | yellow with red spotting within<br>1.5 to 2.8            | yellow with red spotting<br>8 to 10  | 1.5 to 2.0                 |



**Figure 4.** Map of the range of *Cypripedium montanum*. (Flora of North America 1993).

Okanogan, Pend Oreille, Spokane, Stevens, Whitman, and Yakima counties (USDA Forest Service and USDI Bureau of Land Management 1994a).

Vrilakas (2002a) reported approximately 200 *Cypripedium montanum* occurrences in eastern Oregon. Based on the Interagency Species Management System (ISMS) electronic database (USDA Forest Service 2003b), Vance et al. (2004) reported 132 documented occurrences in California and 311 in western Oregon. Sixty percent of the occurrences with estimates of abundance reported fewer than 11 individuals. Ten percent of the occurrences reported more than

50 individuals (USDA Forest Service 2003b). The occurrences in western Oregon were reported as small and scattered (Seevers and Lang 1998, Vance et al. 2004). The species' extremely slow growth rate, complex symbiotic relationships with other organisms, and exposure to possibly frequent wildfires, suggest that recolonization of *C. montanum* throughout its range is unlikely (USDA Forest Service and USDI Bureau of Land Management 1994a). The current distribution pattern of scattered small populations may be the natural product of successional processes, reproductive traits, and environmental disturbances over geologic time. However, recent (last 100 years) anthropogenic

alterations in habitat conditions probably have influenced the distribution pattern directly or indirectly as well. Genetic analysis would indicate if populations have deviated from predicted patterns of gene flow.

Region 2 is at the southeastern extreme of the range of *Cypripedium montanum*. The few occurrences of *C. montanum* in Region 2 are limited to two counties (Johnson and Sheridan) in Wyoming, and most occurrences are on National Forest System land. The total number of plants in Region 2 is less than 3,000, with plants distributed unevenly among those occurrences; some occurrences have fewer than five plants while one has more than 1,000 individuals. The contribution of Wyoming occurrences to the overall species' range, distribution, and abundance is small, but their intrinsic vulnerability is rated high. The WYNDD considers this species to be in "moderate decline" (Keinath et al. 2003).

In Region 2, *Cypripedium montanum* is distributed as widely scattered individuals, clumps or colonies within six documented occurrences (five extant and one historic) found on the eastern flank of the Bighorn Mountains in Johnson and Sheridan counties, Wyoming (**Table 1; Figure 5**). Most of the occurrences are located near the Sheridan and Johnson County line just inside the Bighorn National Forest boundary or on nearby lands to the east. They occur in a roughly 2.6 sq. km (1.1 sq. mile) area between 1,500 and 2,134 m (5,000 to 7,000 ft.) elevation. The occurrence covering the largest area (WY-1 in **Table 1**) is located on the Tongue Ranger District of the Bighorn National Forest. This occurrence has more than 2,000 individuals scattered in several subpopulations across about 240 acres spanning Jefferson and Sheridan counties (Karow personal communication 2005). An extension of this site includes a sub-population of about 25 individuals on the north side of a recreation trail. Just south of this occurrence is WY-5 (**Table 1**), located on private land with a colony of a few individuals. Another occurrence (WY-3 in **Table 1**) on the Tongue Ranger District is located in the Wolf Creek drainage, and because of heavy browsing, its size has not been estimated. The southernmost occurrence (WY-2 in **Table 1**) is based on a herbarium specimen collected in 1900 near the headwaters of Clear Creek on the Powder River Ranger District in Johnson County, but no other information is available. This historic occurrence indicates a southerly extension of *C. montanum*'s range in Wyoming. Two occurrences are located in Sheridan County. WY-4 (**Table 1**), located just north of WY-1, consists of two colonies of about 250 individuals widely scattered over about a mile on slopes of a creek drainage. The

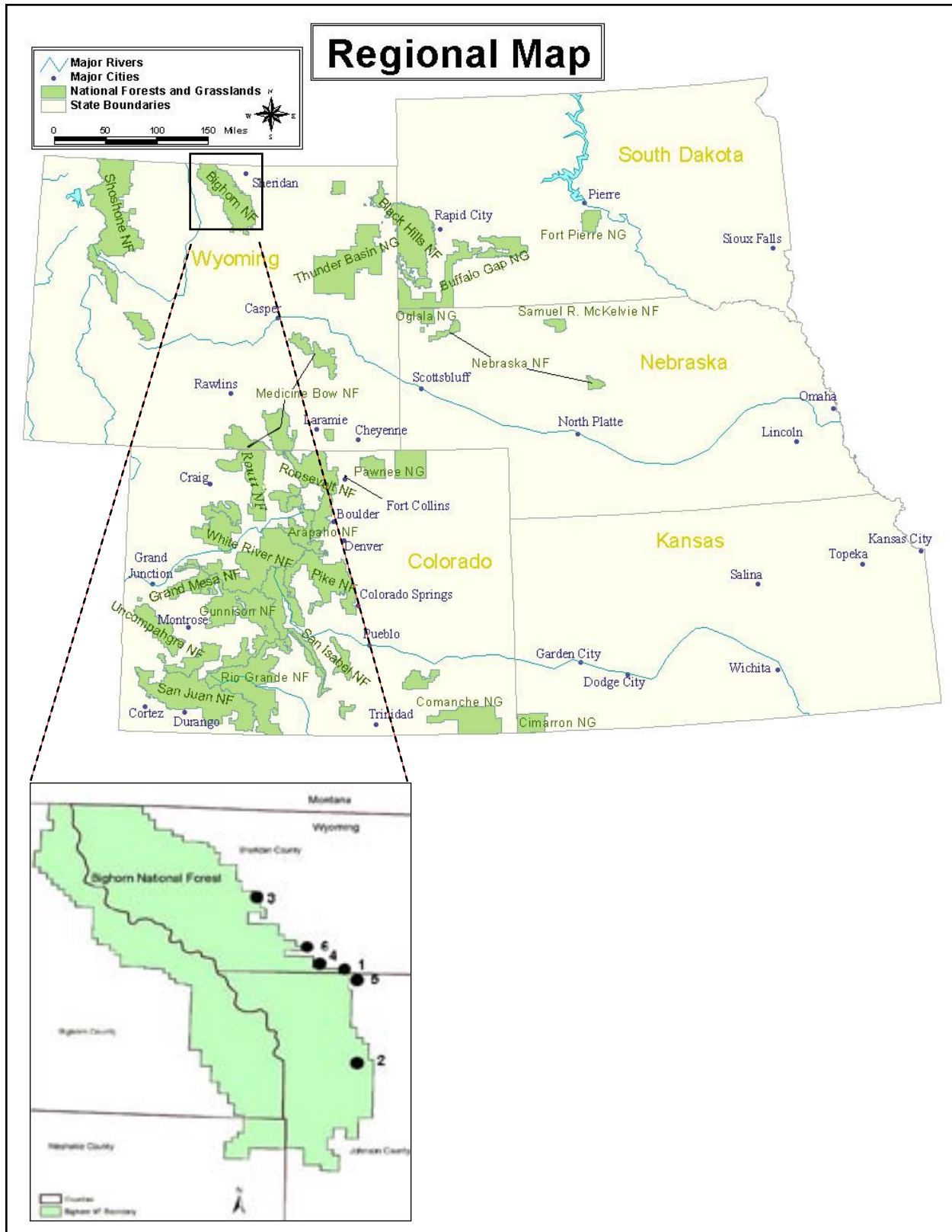
occurrence is located on the Tongue Ranger District and on private land owned by The Nature Conservancy (Wyoming Natural Diversity Database 2005). WY-6 (**Table 1**) is a colony of 150 individuals found scattered on both sides of an unpaved road, suggesting that either a road was constructed through a pre-existing colony or the opening created by the road may provide a favorable environment.

The Wyoming occurrences are peripheral and considered disjunct in relation to the species' range (Keinath et al. 2003). The nearest occurrences of record (MONT herbarium collection, K. Seibert curator) are located in Park, Gallatin, or Judith Basin counties in Montana, more than 200 air miles away.

#### Population trend

*Cypripedium montanum* has declined substantially over its entire range (50 to 75 percent decrease) although trend varies by location (Vrilakas 2002b). Too few occurrences across the range are tracked for a confident discussion of trend. Because *C. montanum* is not tracked in Montana, Washington, or Oregon by their respective state natural heritage programs, documented occurrences for this species have not been maintained. Of 18 specimens of *C. montanum* at the Montana State (MONT) herbarium, 11 are more than 50 years old. The most recent specimen submitted was in 1992. The Washington Natural Heritage Program had 132 occurrences on file; however, it has not tracked the taxon since 1982 (Caplow 2002). The Oregon Natural Heritage Program is no longer tracking *C. montanum* occurrences in western Oregon, but some of the occurrences documented in the early twentieth century are reported to no longer exist (Vrilakas 2002b).

Two hundred fifty-three occurrences existed within the area managed under the Northwest Forest Plan before 1993. Many occurrences were described as having very small populations (USDA Forest Service and USDI Bureau of Land Management 2000). Since then, 127 additional occurrences have been reported, with the majority of these also having low numbers of plants (USDA Forest Service and USDI Bureau of Land Management 2000). The Region 6 electronic database (USDA Forest Service 2003b), which houses occurrence ("known site") data for Survey and Manage species (USDA Forest Service and USDI Bureau of Land Management 2000), documents 437 occurrences of *Cypripedium montanum*, mostly in northern California or southern Oregon. More than half of the occurrences contained 10 or fewer individuals. The increase in documented occurrences since 1993 is



**Figure 5.** Distribution of *Cypripedium montanum* occurrences in USDA Forest Service Region 2. Each occurrence is given an arbitrary number that is also used in [Table 1](#).

primarily due to an increase in the number and scope of surveys as required by Survey and Manage under the Northwest Forest Plan (USDA Forest Service and USDI Bureau of Land Management 1994a).

Unspecified anecdotal reports and old herbarium records indicate that there were more *Cypripedium montanum* occurrences in western Oregon than there are today (Siddall et al. 1979, Meinke 1982). Coleman (1995) reported that in California, the range of *C. montanum* may be shrinking. Inability to relocate plants in locations documented in herbarium records and visible habitat loss support that conclusion (Coleman 1995). Members of the Oregon Native Plant Society have knowledge of *C. montanum* growing in specific locations around the Willamette Valley in Benton and Linn counties dating from the early nineteenth century, but efforts to relocate them have been unsuccessful (Stillwell 2000).

The decline is thought to be gradual over the last century due to factors that include fire suppression, grazing and trampling by livestock, land use practices (e.g., logging, agriculture, urbanization), and collecting. The Final Supplemental Environmental Impact Statement on Management of Habitat for Late-Successional and Old growth Forest Related Species within the Range of the Northern Spotted Owl (USDA Forest Service and USDI Bureau of Land Management 1994b) suggests that fire suppression is an important factor in the overall decline of *Cypripedium montanum*. Seevers and Lang (1998) mention examples of severe damage to populations in logged areas in Oregon and California. In Alberta, Canada, where *C. montanum* is only found in the southwestern part of the province, estimated overall population decline is 20 percent over the past 10 years (Vujnovic personal communication 2002). Losses due to timber harvest have been documented in Oregon (Urban 1997). Coleman (1995) cites an example from Siskiyou County, California, where a pre-logging survey located two populations of 260 and 300 *C. montanum* plants in an area scheduled to be clear-cut. A search of the area several years after timber harvest revealed that only five plants survived at the edge of the clear-cut.

While the trend in occurrences across the species' range appears to be down, the trend in individual numbers within occurrences is variable. In an unpublished report on effectiveness monitoring, Knorr and Martin (2003) revisited 26 of 76 documented *Cypripedium montanum* occurrences on the Klamath National Forest; all but five of the occurrences were relocated. Of these five, three were apparently extirpated due to logging activities that

resulted in the destruction of suitable habitat (Knorr and Martin 2003). Nevertheless, for all 26 occurrences in which the plants were relocated including the extirpated occurrences and those in which no plants could be found, the total plant numbers increased from 713 to 1,536. This could indicate that forest management effects do occur at the population level. Particularly when a population is limited in size, the impact does not need to be widespread to extirpate the entire population.

Because *Cypripedium montanum* populations are dynamic, they change spatially in density and pattern and temporally in number or size (Vance personal observation). Distribution within a population, based on visible stem counts, may change from year to year, presumably because of recruitment through seedlings and/or new emergence or re-emergence of stems of an existing clone (Tamm 1991). Since different stems of older plants may re-emerge in subsequent years, it is difficult to ascribe mortality to those stems that do not re-emerge in any one year. The root crown of the rhizome below ground may develop a new shoot at one location on the rhizome, and in the following year, a different shoot. With only aerial stem counts as a demographic tool, it is difficult to ascertain a real trend in population change unless censuses are taken over multiple years.

By using a map based in part on analysis of herbarium vouchers and historic data coupled with extant occurrences, it may be possible to show that within the range of *Cypripedium montanum*, there have been increasing discontinuities and evidence of an increasing number of disjunct populations. This might support the inference that habitat loss from severe fires, clearcut logging, and other changes to the landscape in the last century may have caused the extirpation of entire occurrences (Knorr and Martin 2003). Despite these effects on the distribution, the current distribution may not have been radically different in pattern and range from that of the pre-settlement period. The range and distribution of *C. montanum* probably always had discontinuities and areas where abundance was low. Although more fragmented, the distribution today may be derived from relict populations of the late Holocene from a more contiguous range dating back to the early Holocene when a former landscape was possibly made more favorable by retreating glaciers (Whitlock 1992, Case 1994).

#### Habitat

*Cypripedium montanum* occurs in a variety of montane forest and transitional habitats across the

species' range. What is known of the ecology of this species is based largely on information from local and regional site reports. Habitats vary in moisture regimes, substrates, and plant associates (Kagan 1990, Seevers unpublished reports). *Cypripedium montanum* occurs most frequently in mixed coniferous forest community types in California (Kaye and Cramer 2005). Occurrences occupy mixed conifer, mixed conifer-hardwood forests, and forest edges. They may be associated with shrubs and various forest graminoids and forbs, such as *Calamagrostis rubescens* (pinegrass), *Maianthemum racemosum* (feathery false lily of the valley), and *Fragaria* spp. (wild strawberry). *Pseudotsuga menziesii* (Douglas-fir) was often the reported canopy dominant and is highly associated with *Cypripedium montanum* in Washington, Oregon, and California (Seevers and Lang 1998, USDA Forest Service 2003b).

Habitats that vary from moist to dry and from canopied to open slopes in Region 2 are also found within localized areas elsewhere across its range. Coleman (1995) reported that *Cypripedium montanum* grows in both moist and dry conditions in California. A typical moist habitat is along streams under or near *Cornus stolonifera* (dogwood), *Rhododendron occidentale* (western azalea), with *Clintonia uniflora* (queen's cup bead-lily) as a ground cover (Coleman 1995). The Jepson Flora (Hickman 1993) describes *Cypripedium montanum* habitat as moist areas, dry slopes, mixed evergreen or coniferous forests. Peck (1961) cites moist open woods, and Hitchcock et al. (1969) cite dry to moist, open to shrub or forest-covered valleys or mountainsides. Information from the ISMS database (USDA Forest Service 2003b) indicates that *C. montanum* grows in coniferous, deciduous, and broadleaf evergreen forests, openings, and thickets, and around shrubs on open slopes.

*Cypripedium montanum* populations in Region 2 grow primarily in the southern Rocky Mountains steppe—open woodland—coniferous forest—alpine meadow province of the Bighorn Mountains section (M331B) (ECOMAP 1993 cited in USDA Forest Service 1994). Based on mapped information, the potential vegetation is Douglas-fir forest and western spruce/fir forest (50 percent) and wheatgrass/needlegrass/shrub-steppe (50 percent). The montane zone of the Bighorn Mountains is characterized by *Pinus ponderosa* (ponderosa pine), which dominates on lower, drier, more exposed slopes, and *Pseudotsuga menziesii* and *Abies* species, which are dominant in higher, moister, more sheltered areas. After fire in the upper part of the montane zone, *Populus tremuloides* (quaking aspen) or

*Pinus contorta* (lodgepole pine) usually replaces the original forest trees (Bailey 1980, Knight 1996).

The habitats of *Cypripedium montanum* occurrences in Region 2 are consistent with the mixed forest habitats elsewhere in its range, which often represent a transition between forest and shrub-steppe/prairie communities (**Figure 6**). On the east flank of the Bighorn Mountains, *C. montanum* occupies shady and moist habitats as well as more open and drier habitats in *Pinus ponderosa*, *Pseudotsuga menziesii*, and *Picea engelmannii* (Engelmann spruce) forests. The occurrences are located on east- to north-facing slopes and in riparian zones on the east slope of the Bighorn Mountains where average precipitation is approximately 533 to 635 mm (21 to 25 inches) per year (Curtis and Grimes 2004).

The soil in which *Cypripedium montanum* grows in Region 2 is variable, ranging from gravelly to silty loam that may have granitic, sedimentary, or limestone substrate, but typically is well drained. The largest and most extensive of the *C. montanum* populations (WY-1 in **Table 1**) is in a drainage consisting of upland, riparian, and open and forested habitats. There the substrates are well-drained soils of the Agneston (sandy loam)-rubble land association (granitic substrate) or of the Cloud Peak-Eutroboralfs-Agriborolls association (sedimentary substrate). WY-4 (**Table 1**) is also found upslope but near riparian habitat in soil classified in the Agneston-Rubble land association (Galloway 2004, unpublished soil survey, USDA Forest Service, Bighorn National Forest). The Cloud Peak series consists of moderately deep (depth to calcareous layer, 30.5 to 61 cm [12 to 24 inches]), well-drained soils that formed in residuum and slope wash alluvium. Cloud Peak soils may be on upland hills and ridges with slopes of 6 to 75 percent. Favorable habitat in granitic-based soils of the Agneston series that are erosion prone would probably be located on shallow and vegetated slopes or within the rooting area of trees and shrubs that anchor the soil. Thus, the steepness of upland slopes may be a factor limiting geographic spread of *C. montanum* in drainages.

Location data indicate that *Cypripedium montanum* across its range is able to grow on a wide variety of substrates, including ultramafic igneous substrates and limestone (USDA Forest Service 2003b). Although other species of *Cypripedium* are known to grow in marshy habitats (Cribb 1997), evidence indicates that well-drained and well-mulched soil affords ideal conditions (Cech 2002, 2003b). Little is known about the species' soil requirements in the field;



**Figure 6.** Photographs with trail and creek transecting two distinct habitats of *Cypripedium montanum* in Region 2: (A) Rocky upland slope dissected by creek and *Populus* community. (B) Upland trail on edge of *Pinus ponderosa*/ *Picea engelmannii* community/forb meadow; *Balsamorhiza sagittata* dominant in herbaceous community. Photographs by Tucker Galloway, USDA Forest Service, used with permission.

however, those who grow orchid species in culture find that *C. montanum* is particularly sensitive to excessive moisture, especially in the winter when there is less light (Doherty (1997). Whitlow (1983) suggests that *C. montanum* and *C. fasciculatum* require slightly acidic, sandy soil, and fairly dry conditions. Personal observations in the field at numerous sites confirm that the soil is well drained, and although moist in spring during the growing season, by summer it is dry unless moistened by infrequent showers.

Prolonged soil dampness occurs in the winter when soil temperature is near or at freezing, thus inhibiting pathogenic damping-off fungi and molds. It is thought that mycorrhizal fungi associated with *Cypripedium montanum* may serve to inhibit other pathogenic fungi under such conditions, but when soil is compacted or anaerobic, fungi are prone to attack the root crown (Cech 2002). Roots from seedlings that had not yet emerged and were dug up in spring 2005 were covered with unidentified fungal hyphae

(Luoma personal communication 2005). Establishment of new populations requires suitable conditions for the orchid's symbiont. The specific habitat conditions are not known, but can be presumed to be moist, shady, and with adequate organic material to support growth of heterotrophic fungi.

In western montane ecosystems including the Rocky Mountain Region, fire shapes the landscape and influences habitat. Harrod et al. (1997) stated that historically suitable habitat conditions for *Cypripedium fasciculatum*, a sympatric species, likely shifted across the landscape over time or were found in fire refugia. Greenlee (1997) suggests that in the USDA Forest Service, Northern Region, *C. fasciculatum* is distributed as a metapopulation linked by recurrent extinctions and recolonizations over time. In this view, populations moved across the landscape as suitable habitat appeared and disappeared from disturbances and successional changes that occurred over time. Although the effects of disturbance (type, frequency, intensity, and duration) on *C. montanum* and associated habitat have not been well studied, this model may apply to *C. montanum* as well.

### Reproductive biology and ecology

There is little published research on the genetics, growth habit, and reproductive biology of *Cypripedium montanum*. However, studies of other *Cypripedium* species and other orchid genera can provide some insight into the genetics and reproductive biology of this species (Luer 1969, Case 1987, Ballard 1990, Hadley 1990, Sheviak 1992, Harrod and Knecht 1994, Knecht 1996, Proctor et al. 1996). *Cypripedium montanum* is self-compatible but requires an insect vector for successful pollination. The importance of a pollinating vector for producing seed indicates that the species relies on attracting a pollinator for seed production to extend its distribution as well as to maintain a diverse gene pool (Knecht 1996, Lipow et al. 2002). All *Cypripedium* species are non-rewarding (no nectar or pollen benefits to the pollinator) and achieve pollination by attraction and structural design (Dressler 1981, Cribb 1997). In other deceptive non-rewarding orchid species, increasing the floral density in a cluster may result in attracting more pollinators, resulting in greater reproductive success (Davis 1986). Increasing the number of flowering stems may be most successful in attracting pollinators if the population is scattered, but it may not be as effective as if flowering plants are clustered together in locally high abundance (Sabat and Ackerman 1996).

Releasing specific volatile compounds during anthesis may be one of the primary means of luring a pollinator into the lip of the orchid. Specialized scent-producing hairs are strategically located in the inner surface of the lip and continue around to the rear of the lip near the exit (Lee 2004). This odor may draw the insect to the back of the labellum and toward the exit adjacent to the anther. The scent of *Cypripedium montanum* has been reported as pleasant or sweet (Sheviak 1992, Coleman 1995, Cech 2002). Urban (personal communication 1997) reported that *C. montanum* had a light vanilla scent. Lee (2004) isolated volatile compounds emitted by *C. fasciculatum* and *C. montanum* using solid phase microextraction (SPME) and found that the fragrance of *C. montanum* predominantly consisted of isomers of caryophyllene, an important source of fragrance. In combination with other volatile organic compounds, caryophyllene forms a marker aroma that is characteristic of a species' flower (Overton and Manura 1999).

As with most other *Cypripedium* species (Cribb 1997), *C. montanum* is pollinated by bees (Bernhardt personal communication 2005). Luer (1975) observed several small black bees, tentatively identified from a photograph as a banded species of *Lasioglossum*, pollinating a *C. montanum* flower. Large bumblebees (*Bombus* spp.) may be excluded from the pouch by the size of the opening (Luer 1975). Bernhardt and Vance collected pollinators from two different sites in Oregon for a study on the pollination ecology of *C. montanum*. They were all small bees (Hymenoptera) from 5 to 9 mm in length (unpublished data). The three primary bee families represented by the visitors of *C. montanum* were Halictitidae, Andrenidae, and Colletidae (Bernhardt personal communication 2006). These generalist foraging bees gather nectar and pollen from flowering plants associated with *C. montanum*, such as *Fragaria* spp. The small bees enter the frontal orifice of the labellum and make their way to the back of the labellum, probably led by olfactory or visual cues. As they enter, they depress the elastic lip near the column base, creating a passageway that leads directly under the stigma and anthers toward one of two openings at the base of the column. As they make their exit through the small basal opening of the labellum, the sticky pollen is deposited on the dorsal side of their thorax or occasionally, the head (**Figure 7**).

Although the *Cypripedium* flower is designed as a "one-way street" that ensures that the insect passes the stigma on the way out, cross-fertilization, or fertilization



**Figure 7.** Small native bee (*Lasioglossum* sp.) emerging from *Cypripedium montanum* flower with sticky pollen contacting the dorsal side of thorax. Photograph by the author.

of any kind, may not always be successful. Tremblay et al. (2005) reviewed variation in orchid sexual reproduction and argue that it is their low reproductive success that results in orchids' unique pollination mechanisms and their diversity. The reproductive success rate in non-rewarding orchid species is typically lower than in orchids that provide a benefit to the pollinator (Tremblay et al. (2005). The average fruit set of North American nectarless orchids is around 20 percent (Lipow et al. 2002). Correll (1950) and Barker (1984) suggest that *C. montanum* has relatively low fruit production, and Barker (1984) believes that pollination is an infrequent event. However, Coleman (1995), who followed fruit production in California populations over a four-year period, found that 792 flowers produced 483 capsules, an average of 61 percent fruit set over all sites and years. Lipow et al. (2002) reported that fruit production of open-pollinated flowers of *C. fasciculatum* varied widely, ranging from 18 percent in Colorado to 69 percent in Oregon.

*Cypripedium montanum* is insect pollinated by small generalist bees, a reproductive strategy that ensures outcrossing of genes. In addition, a wide-ranging distribution across diverse habitats may contribute to increased natural selection and maintenance of genetic diversity (Hamrick and Godt 1989). Although the genetic diversity at the species or population level of *C. montanum* is not known, it could be high. Case (1994) conducted an allozyme analysis and reported that the wide-ranging *C. calceolus*

(greater yellow lady's slipper) had high levels of genetic diversity typical of a widespread, outcrossed, long-lived, herbaceous plant (Hamrick and Godt 1989). Isozyme analysis of plants sampled across the range of *C. fasciculatum*, a wide-ranging, non-rewarding species sympatric with *C. montanum*, genetic diversity was also relatively high. Genetic variation occurring within, more than among, populations (Aagard et al. 1999, Vance 2003) is indicative of healthy, outcrossing populations. Insect-pollinated plants sampled from Oregon populations of *C. fasciculatum* also exhibited relatively high reproductive success (Lipow et al. 2002). In a separate genetic study of Oregon populations of *C. fasciculatum*, the lowest genetic variation occurred in the most isolated population (Vance 2003). Because *C. montanum* populations in Wyoming are highly spatially disjunct from other populations in neighboring states, this may affect the distribution of genetic variation over time. However, without a genetic study, this can only be inferred through the indirect evidence presented above.

#### *Life history*

The small, fusiform seeds of *Cypripedium montanum* are 1 to 2 mm long and are very light, weighing no more 2 µg. Harrod and Knecht (1994) found an average of 3,874 seeds per fruit in *C. fasciculatum*. Correll (1950) reported an estimated 10,000 seeds per capsule in *C. parviflorum*. The capsule usually splits and the dormant seeds disperse before fall precipitation begins. The seeds over-winter in the top layer of soil. If

conditions are favorable and seeds are viable, they may germinate the following spring when soil temperatures rise and soil moisture is adequate, but shoots will not appear above ground for several years.

Orchid seeds, unlike seeds of other flowering plants, lack a differentiated embryo, endosperm, and protective seed coat. A lacy, net-like outer seed coat (testa) covers an inner undifferentiated mass of cells (the proembryo). Because seeds do not have an endosperm, they may lack sufficient nutrients, energy reserves, metabolism, or metabolites to produce a seedling on their own and require a fungal symbiont (Arditti 1967, Rasmussen 1995). The presence of endophytes extracted from protocorms of germinated seed attests to a role of endophytic fungi in seedling development. The largest group of fungi identified from mycelia isolated from the roots of orchid is in the form genus *Rhizoctonia*. *Rhizoctonia* hyphae (fungal filaments) invade and digest the seed coat and outer layers of the cell mass. Digestion of these outer layers produces sugars that the inner cells utilize to grow and develop (Case 1987). This kind of fungal symbiont has proven to be compatible with seeds germinated *in vitro* (Rasmussen 1995) and is postulated as necessary for germination and establishment of *Cypripedium* species in the wild.

Steele (1996) reported *Cypripedium montanum* seed germination rates of about 0.1 percent when using methods that did not include a fungal partner (asymbiotic). The problem of extremely low germination rates needs to be solved if asymbiotic methods are to be used as a source of plants to re-establish extirpated populations (Harding 1998). Propagating *C. montanum* from seed using *in vitro* techniques resulted in 5 to 10 percent germination (Smith and Smith 2004). The germination rate of seed collected in fall 2003 and germinated in petri dishes was sensitive to the medium and also to seed and capsule maturity (Kelsey Creek Laboratories, report to USDA Cooperative State Research, Education, and Extension Service). Germinated seeds with protocorms and roots were planted in soil at the Grand Ronde Overlook Wildflower Institute Serving Ecological Research (GROWISER) in eastern Oregon and, although no aerial shoot had emerged, appeared healthy and growing in the spring of 2005 (observation by the author). These findings are encouraging to continuing research that might result in the technology needed to grow *C. montanum* from seed in the near future.

*Cypripedium montanum* seeds are extremely small and light, and have a hard testa (seed coat).

They are waterproof and can float, suggesting possible dispersal by wind or water (Case 1987, Harrod and Everett 1993, Cribb 1997). Once seeds are dispersed, how long they remain viable is unknown. The spatial distribution patterns of plants on sloping terrain suggest dispersal by surface flow from fall rains or spring snow-melt. In early fall when the capsules release the seeds, thermal-driven wind currents move upward on sunny days, which could disperse seeds upslope. Animal trails are interspersed among the plants; it is possible that ungulates or other animals may disperse seeds (Harrod 1993). The low density and scattered dispersion pattern of this species suggests that there may be multiple dispersal vectors.

If infected by its fungal symbiont, the germinating seed of *Cypripedium montanum* develops into a protocorm out of which grows the first rhizome and starchy roots. It may take several years for the protocorm to grow into a segmented, rhizomatous structure. The elongated rhizome produces a sympodial bud with an emergent aerial leaf (Cribb 1997, Cech 2002). The roots are initiated near the base of the shoot bud (Stoutamire 1991). Each year, the short, non-branching rhizome may produce a new bud at the terminal position with roots growing out from the ventral side of the rhizome just behind the bud (Curtis 1943, Stoutamire 1991).

Many native orchids are completely mycotrophic when immature, spending several years in a complex subterranean symbiotic state. In this state, plants rely on mycorrhizal fungi for water and nutrition (minerals and carbon) until sufficient growth occurs and stored food accumulates for leaf production (Case 1987, Rasmussen 2002). The plant will only develop a shoot after adequate food is stored (Hutchings 1989). It generally takes several years before the seedling emerges with an aerial stem above ground (Huber 2002).

Rhizomes produce buds during the growing season that remain dormant through the winter. If conditions are favorable the next spring, each bud develops into an aerial shoot with a single stem and usually two leaves. The growth of the rhizome is sympodial, and older parts of the rhizome die off so that growth intervals of an excavated rhizome do not indicate the real longevity of the plant. Harrod (1994b), dating orchid rhizomes by counting stem scars, estimated the rhizome he excavated to be from 25 to 30 years old (assuming it was intact). As an orchid plant matures, older buds may also develop stems, thus producing a clonal clump of aerial stems (**Figure 8A**).



**Figure 8.** (A) *Cypripedium montanum* clone of 30 stems in 2005 on road cut in forest burned by wildfire three years earlier, Jefferson County, Oregon. (B) Same clone in 2006 undermined by an unidentified rodent. Photographs by the author.

An aerial shoot may not emerge from a rhizome every year. Differences in local weather conditions or other factors may contribute to whether or not a shoot emerges (Peck 1961, Latham and Hibbs 2001). Census data consisting of *Cypripedium montanum* stem counts in six monitoring plots at the Story, Wyoming location (WY-1 in **Table 1**) show year-to-year changes due to the appearance of new stems in the current year and disappearance of stems counted in the previous year (**Table 3**). This failure to emerge is referred to in the literature as “dormancy,” a common phenomenon observed in terrestrial orchids in which the individual plant may revert to a mycotrophic state (Tamm 1991, Rasmussen 1995, Kull 1998). Annual differences in the number of aerial stems among the six plots also may be due in part to the year-to-year variation in weather conditions. Tamm (1991) concluded in a long-term study of several orchid species that variations in flowering frequency and population levels were explained in part by differences in weather conditions between years.

Stem scars along the rhizome correspond to individual roots, many of which are senescent (Curtis

1943, Harrod 1994). The root crown is often found in the organic soil layer with roots that extend into mineral soil (Vance personal observation 2005). Rhizomes and roots of sampled *Cypripedium montanum* individuals that were excavated for a mycorrhizal study were located 3 to 7 cm (1.2 to 2.75 inches) below the soil surface. In the rich organic layer, roots displayed positive geotropism but were also oriented in varying directions. In at least some orchid species, root orientation appears not to have any detectable function other than to mine the soil for nutrients (Rasmussen 1995). However, the depth of duff, organic, and mineral soil layers, as well as soil texture, influence depth of the root crown and, to some degree, the orientation of the root system.

Spring growth arises from over-wintering buds produced the preceding growing season. However, if fire, late frost, foraging animals, disease, accident, or management practices destroy new spring growth, *Cypripedium montanum*, like other geophytes, cannot replace the lost tissues. Although dormant buds may be present, they will not initiate growth during the current growing season. They will emerge the following year if the perennating buds in the rhizome

**Table 3.** Demographic monitoring of *Cypripedium montanum* on six plots at the Story (WY-1) location on the Tongue Ranger District, Bighorn National Forest from 2003 to 2005. Each circular plot was 1/100 ac or about 3.6 m (11.8 ft.) radius. Total aerial stem and flowering stem number are based on annual census. Capsules were counted in 2004 and 2005 only; percent of overstory canopy was calculated from estimates using a densiometer at plot center. Plots (4, 1, 5) were in a project area that was thinned (small trees/large shrubs) in 2003. Flowering stem % is percent of total stems that flowered, Capsule % is percent of flowers that produced capsules.

| Plot | Treatment | Aerial Stems |      | Net Change |         | Flowering Stems |      | Net Change |         | Flowering stem % |      | Capsules % |      | Canopy % |
|------|-----------|--------------|------|------------|---------|-----------------|------|------------|---------|------------------|------|------------|------|----------|
|      |           | 2003         | 2004 | 2005       | 2003-05 | 2003            | 2004 | 2005       | 2003-05 | 2003             | 2004 | 2004       | 2005 |          |
| 4    | Unthinned | 22           | 24   | 31         | 9       | 8               | 9    | 6          | -2      | 36               | 38   | 67         | 13   | >90      |
| 1    | Unthinned | 21           | 23   | 33         | 12      | 10              | 9    | 11         | 1       | 48               | 39   | 8          | 38   | <10      |
| 5    | Unthinned | 31           | 55   | 53         | 22      | 12              | 11   | 25         | 13      | 39               | 20   | 58         | 4    | >90      |
| 2    | Thinned   | 62           | 76   | 31         | -31     | 40              | 3    | 15         | -25     | 65               | 4    | 67         | 53   | 27       |
| 6    | Thinned   | 27           | 21   | 18         | -9      | 11              | 1    | 12         | 1       | 41               | 8    | 0          | 77   | 58       |
| 3    | Thinned   | 51           | 51   | 55         | 4       | 19              | 0    | 4          | -15     | 37               | 0    | 0          | 20   | >90      |

are not damaged (Barbour et al. 1998). If the buds are damaged, the root system may survive and a new bud may form, or a dormant bud may enlarge, but the plant will suffer a major setback and it may die (Sheviak 1990). *Cypripedium* species that lose all their aerial tissue (stems and leaves) before midsummer will commonly appear the next year but will not bloom (Primack et al. 1994, Vance 2002). Depending on how severely depleted their energy reserves are, plants may require two or more subsequent vegetative seasons before blooming (Case 1987, Primack et al. 1994). This suggests that a plant may require a critical level of carbon from photosynthesis the previous growing season to produce flowers.

It may take two or more years before a seedling produces enough growth to become a flowering plant. In a study of development of five *Cypripedium* species, Curtis (1939) found that 8 to 16 years elapsed from seed germination to flowering. The time interval to flowering varies within an orchid species due to differences in local weather or site conditions (Curtis 1939, Tamm 1991, Kull 1998, Huber 2002). Huber (2002) reported that at GROWISER in eastern Oregon, at least four years elapsed from shoot emergence to flowering. Harrod (1993) found that small *C. fasciculatum* plants could be 12 or more years old before they flowered.

The flowering period for *Cypripedium montanum* extends from March at low elevations through June and occasionally July at higher elevations (Coleman 1995). Flowering of an individual stem may last several weeks depending upon the number of flowers in the inflorescence. Huber (2002) observed that the first time a *C. montanum* plant flowers, the stem produces a single flower, and grows for two more seasons after that before it produces two flowers. For *C. fasciculatum*, the incidence of flowering and the number of flowers were related to the plant's size and age (Lipow et al. 2002). Plant size, maturity, and flowering are linked among individuals of a single *Cypripedium* species in the same environment; but in those environments that offer more favorable conditions, individual stems of a plant may grow more quickly and flower earlier (Cribb 1997). Although *C. montanum* plants usually produce one or two flowers, older *C. montanum* stems can produce three flowers on a single inflorescence and may do so year after year. The leaves are the primary photosynthetic organs that provide energy for flowering. Because flowering is an energy cost to *C. montanum*, the number of flowers on a stem appears to be related to the size and number of stem leaves. No three-flowered stem had fewer than seven leaves (Huber personal communication 2006).

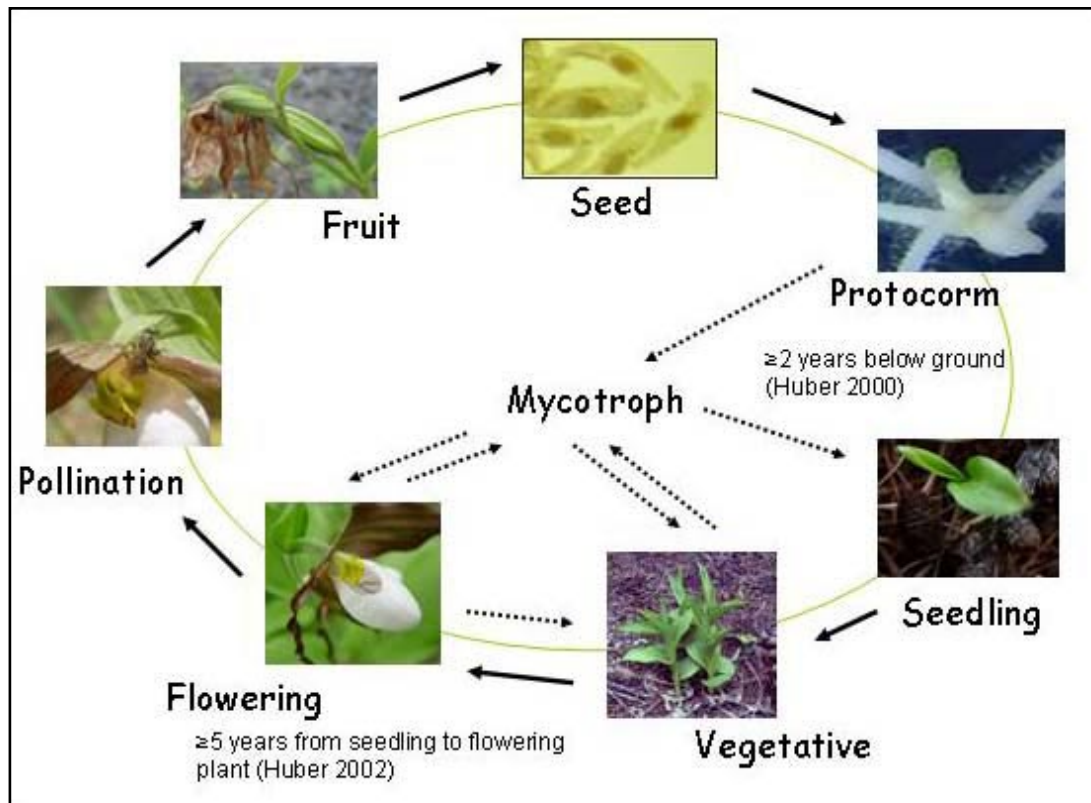
As is the case for most orchid species, *Cypripedium montanum* has a floral life span that lasts about three weeks (Vance personal observation 2006). Fertilization occurs about three to four weeks after pollination (Bernhardt personal communication 2005). This is an unusually long interval between pollination and fertilization in an angiosperm. It appears to be caused by the delay in ovule maturity as the pollen germinates and pollen tubes grows down the style of the pistil to the ovary only to wait for a receptive ovule (Bernhardt personal communication 2005). By late June to mid-summer, swollen ovaries indicate that seeds are developing. When mature ovaries (capsules) desiccate and dehisce, they release thousands of nearly microscopic seeds. The decay-resistant flowering stems will remain on the ground and can be found in spring with opened capsules that still have seeds in them (Vance personal observation 2004). For more details on the flowering and pollination phase of the life cycle please refer to the Reproductive Biology and Ecology section ([Figure 9](#)).

## Demography

Demography of *Cypripedium montanum* has been little studied in Region 2. An orchid's life cycle reported by Tamm (1991) and others (Rasmussen 1995, Cribb 1997) is complex. Because *C. montanum* is heterotrophic and may spend part of its life alternating below and above ground, studies need years of observation to characterize the demography of this species. A demographic study of *C. montanum* in Region 2 is also problematic because of its distribution; few occurrences are large enough to produce meaningful data (Harber and White 1974).

However, despite the difficulties, a demographic study of *Cypripedium montanum* is being conducted on a sample of plants in a large population (WY-1 in [Table 1](#)). A similar study of a smaller population in its entirety might also be useful for comparing the demography of a large and small population. Even though inferences about populations in general cannot be made with any confidence, the information gathered would be useful to managers by helping to identify factors that influence the demography of *C. montanum*.

At WY-1 ([Table 1](#)), monitoring plots were installed in 2003. [Table 3](#) is a summary of census data taken for three years. Three of the plots were located in a fuels reduction project area where small trees and large shrubs were thinned and slash was piled and burned or lopped and scattered. The table indicates year-to-year changes in number of stems and flowering



**Figure 9.** Life cycle diagram for *Cypripedium montanum* indicating the two mycotrophic phases: protocorm-to-seedling and mature plant. Brown bar indicates subterranean state of plant in the mycotrophic phase of life cycle.

stems. The project called for thinning and burning that were expected to occur in 2003 in the North and South Piney Creek drainages immediately west of Story in Wyoming's Sheridan and Johnson counties. Six plots were installed in 2003 originally to monitor fire and thinning effects on *Cypripedium montanum* population dynamics and demography. However, the prescribed burning did not occur and thinning was minimal in the immediate vicinity of the plots (Karow personal communication 2005). There appears to be no relationship between overstory cover (measured with a densiometer) and flowering success (measured by relative flowering). Yet flowering appeared to be reduced for individuals in the thinning and pruning treatment area (**Table 3**). The difference in flowering between 2003 and 2004 may have been related to local variations in weather (Karow personal communication 2005); however, the effect was not distributed across all plots. Flower initiation is usually influenced by events in the previous year (Tamm 1991). Recording the presence of aerial stems that may fluctuate from year to year is time consuming and introduces error. Other demographic factors may vary as well. The percent of developed capsules averaged over six plots was 33 percent in 2004 and 34 percent in 2005, and ranged from 4 to 77 percent. On one plot, 77 percent of

flowers developed into capsules, a very high value for a non-rewarding orchid (Neiland and Wilcock 1998). However, an extreme change in reproductive success, in which relative capsule production dropped from 58 percent in 2004 to 4 percent in 2005 (**Table 3**), may indicate an external causal agent.

Demographic assessment of a genetically and structurally complex population is problematic because aerial stems of a single individual do not always appear above ground each year and ramets are difficult to distinguish from genetically distinct individuals. Nevertheless, juveniles and seedlings should be distinguished from mature plants. It is important to find newly emergent seedlings, which, depending on the time of the year surveys are conducted, may be difficult to detect. Thus, the population structure can be assessed based on age and size as well as maturity. Through evaluating a set of developmental stages, the demographic data can show differences among years in the fundamental factors that determine population health: reproductive success and recruitment.

In occurrences throughout Region 2, *Cypripedium montanum* demography may be influenced by disturbance or changing edge effects, as was found in

eastern Oregon. There, in a large population (more than 2,000 individuals), immature plants were found to be most common at forest edges and in openings in the canopy created by logging and road building (Huber 2002). A general approximation for optimal canopy cover may be 50 percent depending on slope and aspect (Huber personal communication 2004). This supports findings elsewhere that plant survival is higher in shelterwood cuts than in either clear-cut or uncut forests (Kaye 1999).

Across its entire range, *Cypripedium montanum* historically existed in a landscape influenced by wildfires that varied widely in frequency and intensity (Agee 1993). The role of fire in *C. montanum* ecology is complex. Urban (1997) documented strong “recolonization” by *C. montanum* of thirty-year-old plantations where fire was used to prepare the site for planting. The first response was a rapid increase of *Ceanothus velutinus* (snowbrush), with an immediate abundant and vigorous reappearance of *Cypripedium montanum*. Based on the several years’ time needed for *Cypripedium* seedling establishment, the immediate reappearance of plants in the burned area suggested that the fire did not destroy the original plants. Other observations suggest that fire, depending on its intensity, will have different effects on the demography of *C. montanum* populations (Knorr and Martin 2003). Two-year post-fire observations of *C. montanum* on the east side of the Cascade Range in Oregon indicated that post-fire survival and population persistence following a stand-replacing fire depend not only on survival of the root crown, but also on recovery of shrubs and other understory components that can provide shade during critical flowering and fruit development stages.

Historic wildfires were probably an important agent in creating patchy distributions and small populations across the range of *Cypripedium montanum*. Small populations that are also isolated may be at risk for erosion of genetic variation because the ability to outcross through pollination vectors may become limited (Kery et al. 2000). The dynamics of small, peripheral populations such as *C. montanum* in Region 2 may be influenced by gradients in biotic factors and competition as well as by larger-scale processes related to their location on the possibly shrinking margin of the species’ range (Antonovics et al. 2006). It would be difficult to determine effective population size for *C. montanum* or the number and distribution of small populations required to maintain historic levels of genetic variation without an understanding of the historic distribution of the species, its breeding system,

and a baseline analysis of genetic variation within and among populations supported by accurate spatial data.

### Community ecology

*Cypripedium montanum* grows on a wide variety of substrates within and on the edges of mixed conifer woodland communities at various successional stages. Across the species’ range, its habitat varies from climax old-growth coniferous forests to early successional communities following wildfire or other major disturbances. In Region 2, *C. montanum* often grows in communities dominated by *Populus tremuloides* and *Pinus contorta*, species that commonly are colonizers of burned or disturbed landscapes. The Story location (WY-1 in [Table 1](#)) spans three distinct habitats with plant associations that have species unique to each. A list of associated plant species compiled from the demographic monitoring plots at WY-1 includes species representing mesic to dry habitats. Common species at WY-1 include shrubs of the temperate montane steppe such as *Symphoricarpos* spp. (snowberry), *Amelanchier alnifolia* (alderleaf serviceberry), and *Spiraea betulifolia* (white spiraea). Other common associates ([Table 4](#)) include species of open meadows and dry coniferous forests, including *Balsamorhiza sagittata* (arrowleaf balsamroot), *Lomatium* spp. (desertparsley), and *Lupinus* spp. (lupine), as well as more mesic and shade-tolerant forest species such as *Goodyera oblongifolia* (western rattlesnake plantain), *Disporum trachycarpum* (drops of gold), *Arnica* spp. (arnica), *Galium boreale* (northern bedstraw), and *Thalictrum* spp. (meadow-rue). These associated species are indicative of *C. montanum* both as a colonizer after fire and as a long-lived, late successional species.

*Cypripedium montanum* appears relatively intolerant of intense competition, and across its range, this species appears to reproduce best in microsites that lack a dense herbaceous layer (Vance personal observation). Aggressive colonizing species, such as *Pteridium aquilinum* (bracken fern) with its extensive rhizomatous growth or graminoids that form dense mats, may create unfavorable habitat for the species. More study is needed to clarify the dynamics of *C. montanum* demography in relation to the plant community and the influence of competitive or invasive plant species.

*Cypripedium montanum* is visited by a variety of animals, primarily insects, including members of the orders Diptera (flies) Lepidoptera (butterflies and moths), Coleoptera (beetles), and Hymenoptera (wasps, bees, ants). Only bees pollinate the orchid, so most other

**Table 4.** Species richness based on species survey of six, 1/100<sup>th</sup> acre *Cypripedium montanum* monitoring plots at the Story (WY-1) location on the Tongue Ranger District, Bighorn National Forest.

|                                |   |                               |                             |
|--------------------------------|---|-------------------------------|-----------------------------|
| <b>Trees</b>                   | <b>Forbs</b>                                  | <i>Fragaria virginiana</i>    | <i>Solidago</i> sp.         |
| <i>Pinus contorta</i>          | <i>Achillea millefolium</i>                   | <i>Galium boreale</i>         | <i>Taraxacum officinale</i> |
| <i>Pinus ponderosa</i>         | <i>Anemone</i> sp.                            | <i>Galium</i> spp.            | <i>Thalictrum</i> sp.       |
| <i>Pseudotsuga menziesii</i>   | <i>Antennaria</i> sp.                         | <i>Geranium richardsonii</i>  | <i>Thermopsis</i> sp.       |
| <i>Populus</i> sp. OP*         | <i>Apocynum</i> sp.                           | <i>Geranium viscosissimum</i> | <i>Trifolium</i> sp.        |
|                                | <i>Arnica cordifolia</i>                      | <i>Geum triflorum</i>         | <i>Viola</i> sp.            |
| <b>Shrubs</b>                  | <i>Arnica</i> sp.                             | <i>Goodyera oblongifolia</i>  |                             |
| <i>Acer glabrum</i>            | <i>Aster</i> sp.                              | <i>Helianthus</i> spp.        | <b>Graminoids</b>           |
| <i>Amelanchier alnifolia</i>   | <i>Balsamorhiza sagittata</i>                 | <i>Lilium</i> sp.             | <i>Carex</i> sp.            |
| <i>Ceanothus velutinus</i>     | <i>Calochortus</i> spp.                       | <i>Lomatium</i> sp.           | <i>Juncus</i> sp.           |
| <i>Crataegus douglasii</i>     | <i>Campanula</i> spp.                         | <i>Lupinus</i> sp.            | <i>Phleum pratense</i>      |
| <i>Prunus virginiana</i>       | <i>Castilleja</i> spp.                        | <i>Maianthemum racemosum</i>  |                             |
| <i>Rosa</i> spp.               | <i>Comandra umbellata</i> var. <i>pallida</i> | <i>Mertensia ciliata</i>      |                             |
| <i>Rubus parviflorus</i>       | <i>Corallorhiza</i> spp.                      | <i>Maianthemum stellatum</i>  |                             |
| <i>Shepherdia canadensis</i>   | <i>Crepis</i> spp.                            | <i>Monarda fistulosa</i>      |                             |
| <i>Spiraea betulifolia</i>     | <i>Cynoglossum officinale</i>                 | <i>Osmorhiza</i> sp.          |                             |
| <i>Symphoricarpos</i> sp.      | <i>Cynoglossum officinale</i>                 | <i>Potentilla gracilis</i>    |                             |
| <i>Toxicodendron rydbergii</i> | <i>Epilobium angustifolium</i>                | <i>Senecio</i> sp.            |                             |

\*OP = located just out of plot

insect visitors are engaged in herbivory or are incidental. Many of these insects feed on pollen and nectar in flowering plants associated with *C. montanum* that also support the pollinating bees with food. *Cypripedium montanum* evolved in habitats occupied by native ungulate species. Animal trails often meander through colonies of *C. montanum*, and browsing is reportedly light. However, ungulate browse can be severe (Karrow personal communication 2005). It is unknown whether *C. montanum* evolved with severe browsing pressure; browsing of the orchid may indicate a lack of preferred ungulate browse species.

Like other orchid species, *Cypripedium montanum* forms a vital ecological relationship in its mycorrhizal association with fungi (Curtis 1939, Rasmussen 1995, Shefferson et al. 2005). Mycorrhizae associated with orchids are diverse but also may be fairly specific (Shefferson et al. 2005). More than one species can colonize orchid roots even after the orchid appears to be autotrophic (Kristiansen et al. 2001). A recent journal article and an unpublished report identified mycorrhizal fungi extracted from roots of *C. montanum* using PCR amplification of fungal genes. Shefferson et al. (2005) found that 10 of 12 *C. montanum* plants sampled in northern California had fungi in the family Tulasnellaceae associated with their roots. Luoma (personal communication 2005) noted that many of the

sequenced samples of PCR-amplified DNA extracted from roots of plants growing in Oregon and Idaho closely matched organisms in the order Tulasnellales. Although they also found a sample that matched species of the truffle-forming genus *Rhizopogon*, the taxonomy of this fungal symbiont requires more clarification.

The relationship between mycorrhizal fungi and orchids is complex; it varies over the life cycle of the plant and is regulated by changes over a season (Anderson 1992). Orchid mycorrhizae are different from other mycorrhizal systems in which the green plant is the source of energy. In orchid mycorrhizal systems, the fungus is the source of energy until the plant becomes phototrophic (Rasmussen 1995). This enables the orchid to be heterotrophic throughout its life and helps to buffer changing habitat conditions.

The seeds of *Cypripedium montanum* plants, like those of other orchid species, require infection by a specific mycorrhizal fungus to germinate (Arditti 1967, Wells 1981, Doherty 1997). *Cypripedium* species are completely mycotrophic for several years after germination, existing in a subterranean condition. Immature plants rely on the fungus for water and nutrition until sufficient growth occurs and enough stored energy accumulates to allow leaf production (Rasmussen 1995).

Once an orchid reaches maturity and becomes autotrophic, the degree of dependence on the symbiotic fungal species may decrease (Rasmussen 1995, Doherty 1997). Whitlow (1983) suggested that once *Cypripedium* becomes wholly autotrophic, the role of the fungus ceases. However, otherwise phototrophic individuals have been observed spending several years underground. Whether they return to a mycotrophic state in that leafless condition is not known, but it is suspected that they do (Rasmussen 1995, Smith and Read 1997). Although the relationship is not fully understood, symbionts may be necessary for adult plants as well as for establishment of seedlings and may be a more limiting factor to the persistence of populations and their spread than climate or other ecological factors (Cribb 1997).

Establishment of new populations requires suitable conditions for forest fungi. What constitutes suitable conditions is not known, but can be presumed to be shady, with adequate organic material to support growth of heterotrophic fungi, and moist at least for part of the growing season. Infection of plant roots occurs in the upper organic soil layers, suggesting that the mycorrhizae do well in aerated soil with woody debris or other carbohydrate sources available (Rasmussen 2002). The dynamic relationship between the plant and fungal symbiont is thought also to be affected by changes in the microenvironment (Sheviak 1990).

New research is revealing the mycorrhizal relationship to be ecologically complex (Rasmussen 2002). Orchid mycorrhizal fungi may also form mycorrhizae with roots of neighboring live, woody plants (Rasmussen 2002, Shefferson et al. 2005). Stable isotope analysis of orchid and non-orchid tissue of *Cypripedium fasciculatum* revealed that carbon was being made available to the orchid through digestion of the fungus in the root cells (Whitridge and Southworth 2005). Orchid mycorrhizal fungi may be saprophytic decomposers of herbaceous and woody debris, but may simultaneously be parasitic or symbiotic with other species. The association of *C. montanum*, a heterotrophic orchid, with western forest trees and woody shrubs suggests that its fungal symbionts may concomitantly form ectomycorrhizal associations with *Pinus*, *Populus*, or *Salix* (willow) species. Research is beginning to demonstrate that several fungal types associated with orchids play different functional roles, suggesting a strong ecological role that the subterranean fungi play in the demography, fitness, and distribution of the orchid (Rasmussen 2002).

## CONSERVATION

### *Threats*

In Region 2, the primary threats to *Cypripedium montanum* are more likely to be inferred from its distribution and habitat than from specific events. Having no historic measure of the species' range, distribution, or abundance precludes pinpointing the factors that may have led to its current status. The greatest threats can be generalized as those that result in the destruction of plants or that alter microsite conditions (e.g., soil, moisture, light regime) so that *C. montanum* cannot complete its life cycle. If a disturbance is widespread, an entire population could be jeopardized. Human activities, including those that involve mechanical alteration of the soil or removal of overstory, severe wildfires, browsing or trampling by large animals, and plant collecting, appear to be the greatest potential threats to the persistence of *C. montanum*. Natural and human disturbances that alter the orchid's habitat may interact with animals so that predation or animal disturbance may be magnified. These complex and indirect impacts are not often recognized but apparently do occur (**Figure 8**). The species is especially vulnerable to these threats in Region 2 because of its isolated and small populations. There has been no formal analysis or assessment for *C. montanum* designed to evaluate the risk of extirpation or population viability loss from natural disturbances or other perturbations, such as invasive species, fire, or human activities.

#### Human activities resulting in environmental disturbances

Potential threats due to human activities include developments (e.g., trail maintenance, road widening) that foster exotic species encroachment, tree harvest that alters the light regime by removing overstory and/or understory cover, and mechanized equipment used for logging, road construction, or fire fighting that can compact the soil and remove the duff and the organic layers. Plants and habitat can be adversely affected by livestock, off-road motorized recreation, and non-motorized recreation that expose plants to trampling (Latham 2001). The impacts of these activities on *Cypripedium montanum* are currently unknown because no monitoring or studies have specifically evaluated these threats to populations or individual plants.

Mechanical activities or natural phenomena, such as colluvial or alluvial activity on unstable slopes,

that disturb soil, remove duff, and expose or damage the rhizome and roots may kill *Cypripedium* plants (Harrod 1994, Knecht 1996). The adventitious roots of *C. candidum* were found to be particularly sensitive to disturbance; damaged roots were replaced only slowly from the youngest rhizome sections (Stoutamire 1991). Several occurrences of *C. montanum* in Region 2 are near roads on slopes with rocky and/or sandy soils. Rapid run-off from heavy rain during thunderstorms or flash flooding of streams when storms coincide with melting snow pack may cause erosion on steep slopes lacking vegetative cover. Soil instability and alluvial soil movement may be exacerbated by management activities such as road widening or culvert installation. The largest occurrence (WY-1 in **Table 1**), which has more than 2,000 individuals, is on National Forest System land located in a backcountry area designated for motorized as well as non-motorized recreational use on unimproved roads and trails (USDA Forest Service 2005). This may increase the likelihood of off-road vehicles impacting plants close to roads and trails.

Forest management activities may have variable effects on *Cypripedium montanum*. Anecdotal reports suggest that timber removal using mechanized equipment and resulting in significant loss of overstory is usually detrimental. Knorr and Martin (2003) reported that of 26 sites where *C. montanum* occurred, all plants on three sites were extirpated due to logging disturbance that destroyed suitable habitat. The report noted that although protection may have occurred during logging, post-logging activities that included trail building, roadside salvage sales, replanting and subsequent thinning adversely impacted populations. Urban (1981 cited in Barker 1984) reported severe declines in local populations when canopy was removed. In a report to district rangers on the Klamath National Forest, field botanists indicated that while some populations tolerated partial cuts, this was the exception not the rule (Barker 1984). In Siskiyou County, California, a pre-logging survey by the USFS recorded two populations, totaling 560 plants (based on a count of aerial stems) in a planned clear-cut unit. A search of the area several years after it was harvested revealed that only five plants had survived on the edge of the clear-cut (USDA Forest Service 2003a).

The mechanized equipment used in tree harvesting and road building can alter the species' habitat by compacting the soil, removing protective cover or duff, or exposing roots or the plant's central rhizome. Demographic monitoring data indicated that individual orchids in a clearcut declined dramatically in number and performed poorly through seven years

post-tree harvest (Kaye 1999). The author, however, cautioned that more data from replicated studies are needed, as this was a single specific example and should not be generalized.

The effects of management can also be indirect and difficult to evaluate. On the Deschutes National Forest in Jefferson County, Oregon, almost all of the *Cypripedium montanum* individuals that survived a stand-replacing fire were located on the banks of a USFS road, where the fire did not burn as intensely. However, a few of the survivors have become victims of soil instability, or damaged by increased exposure following the burn (Vance personal observation 2004, 2005).

### Severe wildfires

Fire appears to have a variable effect on *Cypripedium montanum* depending upon its severity. If *C. montanum* populations occur in areas where fire frequencies have departed from historical values by more than one return interval, the risk of losing key ecosystem components is considered moderate, but in areas where fire frequencies have departed from historical frequencies by multiple return intervals, the accumulation of fuels increases the risk of higher intensity fire (Agee 1993, Arno 2000). Decades of fire suppression throughout the range of *C. montanum* have created fuel conditions that may result in fires of sufficient severity to burn the organic soil layer. Wildfires of sufficient severity that they consume overstory trees and the organic layer pose a threat to the persistence of *C. montanum* populations.

*Cypripedium montanum* is commonly found in ponderosa pine and lodgepole forests throughout much of its range. These dry coniferous forests had frequent, low- to moderate-intensity, surface fires pre-European settlement. The average fire return interval ranged from 5 to 20 years (Arno 1980). Since the early 20<sup>th</sup> century, fire suppression increased the risk of high intensity, stand-replacing fires that can be lethal to *C. montanum* plants. However, within a large wildfire, burn intensity and severity can vary so that some parts of populations could be extirpated while others could be released to repopulate the stand. Knorr and Martin (2003) reported that *C. fasciculatum* (a species sympatric with *C. montanum*) populations were exposed to wildfires that burned hundreds of thousands of acres on the Klamath National Forest in 1987. Five years of monitoring results showed that populations in sites that burned at high intensity were either extirpated or seriously reduced in size. However, at sites that burned at low

intensity, populations appeared to be generally stable or increased in number, had recruitment of juveniles and had some of the largest and most vigorous individuals. These effects persisted for at least 10 years (Knorr and Martin 2003).

In California, Pappalardo (1997 cited in Seevers and Lang 1998a) reported a *Pseudotsuga menziesii* stand containing 50 *Cypripedium montanum* plants burned in 1987. The tree canopy was immediately replaced by an overstory of *Ceanothus integerrimus* (deerbrush). Except for one clump of three stems that survived the 1987 fire, there was no sign of the original population of 50 plants. Severe fires may kill the perennating buds and root crown of the orchid if they are located within a soil zone that is scorched or burned. In addition, if fires remove protective cover, the plants may survive but may not reproduce because they desiccate earlier in the growing season. However, fire also opens up the tree and herbaceous canopies that compete with the orchid for light, nutrients, and moisture, which may result in a positive increase in numbers and flowering of orchids as well as greater reproductive success. Thus, it is not safe to generalize about fire but to assess each fire scenario based on the above factors.

#### Predation and competition

Insect predation and herbivory by ungulates or other mammals occur, but evidence of extirpation by any of the herbivores that have co-existed with *Cypripedium montanum* is rare. The intensity of deer browse on *C. montanum* plants varies from year to year. Deer trails often transect *C. montanum* populations where browsing activity has been observed to be generally haphazard and not heavy. In Oregon, elk and deer browse the upper portions of the plant, including flowers and fruits, but this occasional browsing was thought to have little impact on the viability of the species (Urban 1997). However, the population at the Wolf Creek site on the Bighorn National Forest (WY-3 in **Table 1**) was reported to be so heavily browsed a census could not be taken. Insect herbivory of leaves and flowers generally injures but does not destroy the orchid; however, herbivory of flower parts, particularly the flower's labellum, early in flowering can prevent successful pollination (**Figure 10**).

Livestock can damage *Cypripedium montanum* if they share an area with the species, even if plants are not consumed. Cattle severely trampled and grazed two *C. montanum* populations in an active grazing allotment in Idaho (Vance personal observation 2003). Latham (2001) pointed out that although *Cypripedium* species

were not being grazed, plants located in open areas near streams were likely to be trampled by livestock trailing to water. Botanists in Oregon and California national forests reported that trampling and ground disturbance posed a serious threat to *C. fasciculatum*, a sympatric species (Kaye and Cramer 2005).

There is very little information on the presence of competitors in the form of exotic species or their proximity to *Cypripedium montanum*. In Oregon and Idaho, noxious weeds such as spotted knapweed (*Centaurea maculosa*) and exotic *Bromus* species, grow in proximity to *C. montanum* individuals occurring adjacent to or in road cuts or logged areas (Vance personal observation). However, without long-term monitoring, no conclusions can be drawn about their effects on the species. In Wyoming, the noxious weeds leafy spurge (*Euphorbia esula*) and bull thistle (*Cirsium vulgare*) grow near individuals in WY-1 (**Table 1**). As of 2005, the leafy spurge has not spread and does not threaten *Cypripedium montanum* (Karrow personal communication 2005). However, with the proximity of trails to several locations, the invasion of exotic species is more likely because recreational trails commonly serve as vectors for their spread (Sheley et al. 1999).

In openings where herbaceous and shrub vegetation are dense, root competition for moisture and nutrients increases during dry years (Huber 2002). Below-ground competition is not well understood, but the fern *Pteridium aquilinum* has the potential to suppress growth and reproduction of *Cypripedium montanum* if it becomes dense and spreads throughout the orchid's rooting zone (Stewart 1975, McDonald et al. 2003, Vance personal observation 2005).

*Cypripedium montanum* appears to grow best in dappled or morning light. Observations suggest that competition for light from overtopping species may limit *C. montanum* (Huber 2002). Indirect evidence may be extrapolated from studies of other *Cypripedium* species growing under shrub and tree canopies (Case 1987, Stoutamire 1991). Orchid plants growing under tree and shrub canopies that restrict direct sunlight from reaching the plant cease flowering and develop long and weak stems susceptible to breakage (Case 1987, Stoutamire 1991). Huber (2002) monitored the emergence of *C. montanum* for several years and noted that immature plants do not survive if light is limited by the overstory. Huber (personal communication 2004) also observed that open spaces on the forest floor covered with conifer needles but little other vegetation appeared to produce the most seedlings.



**Figure 10.** Stems of *Cypripedium montanum*, one with a capsule developing and a flower that had aborted (no capsule development). Chewed leaf at lower front of photo; both stems and capsules show signs of damage possibly from insect predation. Photograph by the author.

### Plant and flower collection

Collection from the wild for horticultural, medicinal, or personal purposes can pose a direct and serious threat to *Cypripedium montanum*. Plants are either plucked off at ground level, or are dug up for garden transplant or for obtaining root extracts. The severity of these threats depends on the accessibility of the population and the intensity and method of collection.

Because of their charismatic beauty and long tradition of medicinal use in North America and eastern Asia, *Cypripedium* species historically have experienced extensive collection, causing critical declines in some populations (Cribb and Sandison 1998). In 1995, the World Wildlife Fund listed the lady-slipper orchid genus (*Cypripedium*) among the world's ten most wanted plant or animal taxa, threatened by illegal and unsustainable trade. There has been an enduring tradition of use of roots of *Cypripedium* species for medicinal purposes around the world (Koopowitz 2001). Popular in China, where a number of *Cypripedium* species are found,

the roots of *Cypripedium* species were also used by North American indigenous peoples for a variety of medical problems from back pain to stomach cramps and "female trouble" (Moerman 1998). Cypripedin is a well known chemical extracted from the orchid's roots and used for nervous diseases. In the late 19<sup>th</sup> century, roots of *C. parviflorum* var. *pubescens* were collected by the ton to produce this extract (Koopowitz 2001). The roots have compounds that were reputed to have a relaxing effect on the nervous system and able to promote calm sleep (Cech 2002). In North America, *C. pubescens* was listed in King's American Dispensatory (Felter and Lloyd 1898) as a medicine for treating hysteria, nervous headache, wakefulness, prostration in low fevers, epilepsy, and "indeed, in all cases of morbid irritability of the nervous system." Collecting the roots for making tinctures for medicinal use remains popular today (Willard 1992, Cech 2002).

*Cypripedium* species, prized for their form and beauty, are also widely collected for the ornamental plant trade. Although some species are successfully cultivated, others, like *C. montanum*, have not been

successfully propagated, but the technology to do this is being developed (Smith and Smith 2004). As the worldwide trade in orchids continues to grow, the number of orchids taken from the wild and sold internationally is increasing. Based on CITES figures (2005), between 1983 and 1989, an average of nearly 5 million orchids were traded annually, of which about 80 percent were propagated artificially, leaving around one million that were collected from the wild. This estimate is only for orchids traded internationally and does not include those sold within countries. There are problems in tracking and record keeping because declarations may indicate wild-collected orchids as being artificially propagated or customs records fail to be species-specific (Robbins 1997). A registration system for slipper orchid nurseries that would aid in verification of artificially-propagated species is being developed but is not yet available (World Wildlife Fund 2005).

#### Vulnerability of small populations

The broad range of *Cypripedium montanum* does not equate to abundance because populations are widely scattered and small in size (USDA Forest Service 1994, 2003b). Colonies reduced to single or a few plants increase the likelihood that these occurrences will not persist.

Some of the consequences of very small populations include decreased ability to attract pollinators, loss of fitness, and increased potential for genetic assimilation (Barrett and Kohn 1991). Small populations can be extirpated by perturbations that may affect only a small part of a large population (Harper and White 1974); therefore, smaller populations are more vulnerable to extinction from human and natural causes than larger populations. Small populations, depending upon their proximity to related species, may be vulnerable to hybrid swamping. In this situation, interspecific mating results in the introgression of a sensitive species with a more common species producing hybrid swarms that cause the rarer species to lose its identifying characters (Ellstrand and Elam 1993). Small populations would also be vulnerable to genetic drift (generational change in genetic composition as a result of random effects) or outbreeding depression (through incorporating genes that reduce fitness). In small populations, selection for local conditions or changing environmental conditions may appear as genetic drift (Given 1994, Harris et al. 1984). However, without a regional analysis of genetic structure and effective population size that would include the Region 2 populations in a broad regional sampling or, ideally, sampling across the species' range,

it is impossible to ascertain if genetic composition has changed or is liable to change.

### **Conservation Status of *Cypripedium montanum* in Region 2**

*Cypripedium montanum* populations persist in Region 2 despite having few, small, and widely separated populations. They are situated on the geographic periphery of the species' range, separated by hundreds of miles from other population centers, which contributes to the potential of genetic divergence from the main population (Lesica and Allendorf 1995). The fewer than 3,000 known individuals (based on stem counts) in Region 2 are unevenly distributed among the six occurrences; most are concentrated in a single metapopulation of more than 2,000 plants covering roughly 97 ha (240 acres). The persistence of this metapopulation is supported by conservation management activity primarily because it is located in an active management area (USDA Forest Service 2003d, 2005).

Only two of the six occurrences in Region 2 are rated as having good viability based on population size (Wyoming Natural Diversity Database 2005). The location of a new colony of plants in 2004 suggests that more surveys and inventories will result in the discovery of new occurrences. Until remaining unrecorded populations existing in Region 2 are found and inventoried, knowledge of distribution and abundance remains imprecise. The majority of *Cypripedium montanum* populations throughout its range are small; a large population (more than 500 stems) is relatively rare. However, the implications of this distribution pattern and the genetic consequences of small populations are not understood (Ellstrand and Elam 1993). Although the genetic distribution of alleles of *C. montanum* is unknown, based on the distribution of genetic variability in *C. fasciculatum*, a sympatric species with a comparable distribution pattern, most of the genetic variability probably resides within rather than among populations (Aagard et al. 1999, Vance 2003). Understanding historical pollen and seed dispersal patterns and gene flow that occurred during the post-glacial expansion, and to what degree contemporary rates of dispersal have influenced those patterns may require the kind of phylogeographical approach that was applied to a genetic study of *Trillium grandiflorum* (Griffin and Barrett 2004).

Habitat does not appear to be limiting. *Cypripedium montanum* occurs across a wide range

of elevations and is adapted to a variety of forest habitat conditions that range from cool and shady to dry and open, and to soils that range from deep and loamy to shallow and calcareous. Because much of its habitat is prone to natural disturbance, as indicated by associated species and evidence of past wildfires, it is surprising, given its association with relatively common species, that it is not more abundant (Wyoming Natural Diversity Database 2005).

Despite its apparent adaptability, *Cypripedium montanum* is at the mercy of its habitat at different parts of its life cycle. Vulnerability probably increases during the reproductive phase. If the habitat does not support pollinators, *C. montanum* populations are at risk of losing genetic variability through failing to out-cross. The species is also vulnerable if altered habitat no longer provides a protective overstory. Without shade, prolonged high temperatures, insolation, and drought could cause premature stem and leaf senescence, preventing fruit from forming and seeds from maturing. If the habitat does not support the fungal symbionts required for seed germination and seedling development, then recruitment will fail. Whether populations in Region 2 are recruiting seedlings is not known. Although there are few demographic monitoring data, potential causes for failure to recruit seedlings include pollination limitation, seed inviability, seedling predation, and long maturation period before emergence (Curtis 1943).

Risk assessments are based on identifiable factors that increase the risk of extirpation or damage to an organism. For example, *Cypripedium montanum* is probably at lower risk of extirpation due to invasive exotic plants than to recreational damage; however, no risk assessment has been performed and no potential risks formally identified. Proximity to recreational trails and other sites of human activity that allow easy access to the plants may be a risk factor for three of the largest occurrences (WY-1, WY-4, and WY-6 in **Table 1**). For WY-1, location in a fuels reduction project area and a management area that allows year-round motorized use, as well as proximity to trails in a heavily used recreation area are risk factors. A risk factor for occurrences WY-4 and WY-6 is their proximity to roads and trails in high-use areas. The risk factor for WY-3 (**Table 1**) is its location in an active grazing allotment with reported evidence of extensive herbivory (USDA Forest Service 2005). Investigation might indicate whether cattle are the cause of the herbivory.

## **Management of *Cypripedium montanum* in Region 2**

Implications and potential conservation elements

Persistence of viable *Cypripedium montanum* populations in Region 2 depends on stabilizing populations, because their location on the periphery of the species' range increases their vulnerability to extirpation. Desirable environmental conditions for conserving *C. montanum* in Region 2 include sufficiently large areas where the natural ecosystem processes on which the species depends can occur. The distribution of the species in Region 2 (a few small occurrences distributed across a large area in a variety of habitats) may represent a natural pattern or an inability to colonize new areas. Although populations change with forest succession and natural disturbances that create a mosaic of conditions, there is no assurance that ecosystem processes are functioning properly where the species currently occurs. Maintaining populations with a sufficient number of stems to ensure a breeding population is hampered by the small number and relatively scattered distribution of occurrences and lack of knowledge of what constitutes the size and structure of a healthy, breeding population.

Because the Wyoming populations are limited to the eastern edge of the Bighorn Mountains, analyses of these occurrences as a metapopulation might be appropriate for overcoming sampling problems when analyzing demographic or genetic stochasticity (Menges 1991). Research on the ecology and distribution of *Cypripedium montanum* will help managers to develop effective approaches to management and conservation. Until there is a more complete picture of the distribution and ecology of this species, given the isolation and low number of the occurrences in Region 2, priorities lie not only with conserving all of the known occurrences regardless of their size, but maintaining favorable habitat around these occurrences and corridors between them to the extent possible.

Trends in the demography and the distribution of *Cypripedium montanum* populations in Region 2 are difficult to discern without knowledge of the range-wide or historic distribution and the rate of natural events that shape populations. Based on an examination of vegetational changes in the last 20,000 years in the northwestern United States, Whitlock (1992) found

climate change to be unpredictable in its effects. Therefore, having large natural areas conterminous to the species' range in Region 2 may be the best insurance for enabling *C. montanum* and associated species to adjust their range with climate change. On the other hand, factors should be considered that are critical to maintaining the present individual breeding populations or colonies, such as ensuring that all elements needed for reproduction and recruitment are identified and supported as well as managing microsite and environmental factors that directly affect the orchid's life cycle.

## Tools and practices

### *Species and habitat inventory*

The distribution of *Cypripedium montanum* in Region 2 can be documented best in a database format linked to other important spatial layers such as vegetation and soil maps using Geographic Information System (GIS) technology. Ideally, a map for this species could be developed with multiple layers covering its entire range. This requires inventories that are comprehensive, use appropriate spatial scales, and include revisits of historic occurrences. Surveys are an effective and inexpensive approach for finding new occurrences by searching suitable habitat near known occurrences. However, mapping and analyzing the species' distribution requires inventories and surveys for which training is needed in plant and habitat identification. Inventories for *C. montanum* would be more effective if standardized methods were used that allow inventory data and associated ecological information to communicate with data from more general inventories conducted by other regions of the USFS, other agencies, and the USDA Forest Service's Forest Inventory and Analysis (FIA) program. Systematic surveys that use GIS tools to create maps showing the spatial relationship of temporal ecological processes could include large-scale events, such as wildfires, that can be related to species occurrence data.

Inventories designed for small perennial plant species, such as *Cypripedium montanum*, require an appropriate spatial scale for sampling and should be timed for maximum visibility. Training tools for species identification are important because the vegetative form of *C. montanum* resembles that of other geophytic monocots, particularly *Maianthemum racemosum*. An inventory for *C. montanum* can be complicated by the species' prolonged cryptic growth and the unpredictability of the aerial stems' emergence each

year. A standardized training program and set of criteria for noting life stages that can be employed by managers across the species' range would increase the reliability and consistency of data assessments.

Spatial and temporal differences in survey methods complicate comparisons and summaries. Standardizing inventory procedures would allow a network of sample points across the region and provide valid comparisons at the summary level. Data could be assembled into meaningful regional groupings such as habitat types. A rich data set can be used to explore regional trends in weather, disturbance, or use parameters that can be related to population trends. The Wyoming Natural Diversity Database compiles and stores the most complete and comprehensive information for *Cypripedium montanum* in Wyoming, taken from surveys and sightings that span more than 100 years. The database collects information that is typical of inventories; however, demographic information is sketchy, and no inventory has systematically been conducted of all suitable habitat.

It should be noted that in Region 2, potential habitat might be too coarse of a filter to be practical for inventory purposes, because of the range of habitat types occupied by the six known occurrences of *Cypripedium montanum*. Habitat models might be useful inventory tools; habitats have been modeled for other sensitive plant species in Wyoming (Fertig and Thurston 2003), but this approach might not be appropriate for *C. montanum*, until suitable habitat is well defined. In addition, large areas of what are currently thought to be potential habitat are unoccupied.

### *Population monitoring*

A monitoring program that gathers demographic data and ecological information needed for population viability estimates is useful for land managers, but it is time consuming to implement and maintain (Pavlik 1996). Population trend monitoring, however, is commonly used by rare plant managers because it provides a basis for predicting future population viability at lower cost (Elzinga et al. 1998). A model that can detect population trends under different management and human use scenarios may be designed to be sensitive to disturbance. However, there simply may be too few occurrences of *Cypripedium montanum* in Region 2 to give a model any statistical power, so each occurrence would have to be treated like a case study. Nevertheless, monitoring all Region 2 occurrences could help to identify appropriate management practices that will ensure population persistence.

Annual monitoring would be most desirable for the first several years of a monitoring program in order to gain insight into the demographic dynamics of *Cypripedium montanum*. The longevity of *C. montanum* and length of time for an individual to complete its life-cycle may require repeated measures over a number of years in order to better determine long-term stability of the populations (Tamm 1991, Pavlik 1996). To document important demographic parameters (mainly seedling recruitment, adult stages, mortality, flowering, fruit set), two visits per growing season may be required: at first when seedlings have fully emerged and mature plants are flowering, and again after capsules have matured. The second visit is necessary to determine pollination success as well as fecundity. The most sensitive measure of population stability may be recruitment success. For large populations, using an appropriate sampling scheme can produce valid population trend data. Elzinga et al. (1998) offer additional suggestions regarding sampling design and protocol including the use of photo point monitoring (**Figure 11**).

Gathering data periodically on distribution and population sizes for *Cypripedium montanum* is feasible. Since *C. montanum* has few occurrences, all known occurrences could be monitored. Where occurrences are on private land, enlisting the cooperation of volunteers from interested organizations increases monitoring effectiveness.

A monitoring program that addresses population, habitat, and effects from human activities or natural disturbance might have the following elements:

- ❖ effects of disturbance to include changes in duff, mineral soil, and percent canopy cover
- ❖ demographic changes (e.g., patterns of recruitment, flowering and fruit set, mortality, survivorship, climate, and if possible, microclimate data)
- ❖ long-term effects of particular types of management practices to determine the impact of action on survival
- ❖ prioritizing visits to occurrences with outdated surveys, moderate to high severity burns, past timber sales, and high recreation use
- ❖ reporting changes in occurrence status including new occurrences as quickly as possible to WYNDD and, if on the Bighorn

National Forest, to the forest/district botanists.

Population monitoring on the Bighorn National Forest has been occurring on WY-1 (**Table 1**). The monitoring plots were established within a proposed fuels reduction project area to meet the mitigation requirements for sensitive plants and species of concern, in this case, *Cypripedium montanum* (USDA Forest Service 2003d). Data taken at the plots include an annual census beginning in 2003 of the numbers of aerial stems, flowering stems, flowers and fruits (2004 and 2005) of all individuals within the sample plots (**Table 3**), collection of habitat information including associated species richness (**Table 4**), and a photo series to augment habitat monitoring (**Figure 11**). The fluctuation in stem numbers and other demographic parameters in the individuals sampled over three years indicates how important repeated measures over time are to capturing the demographic dynamics of the population.

Population monitoring of *Cypripedium montanum* is challenged by the fact that plants do not necessarily produce aerial stems every year. Population monitoring is also challenged by the clonal habit of *C. montanum* because it is difficult to determine if aerial stems are ramets of a clone from the same rhizomatous source. For monitoring purposes and to collect demographic information each stem is treated as a countable unit. A clone of multiple stems (ramets) should be recorded as a clone and each stem noted individually as well. It is important that flowering when it occurs is recorded for each stem identified as being a ramet of a clone.

#### *Habitat monitoring*

Because habitat conditions influence demographic changes in populations (Kull 2002), monitoring those conditions that are most directly related to the population dynamics of *Cypripedium montanum* would provide the most relevant and useful information. Identifying factors that constitute favorable habitat for the persistence of the species is a high priority. Those factors might include identifying at each occurrence, plant associations, forest structure by broad life form classes (e.g., tree, shrub, forb, grass, bryophyte), density or cover of the herbaceous layer, and physical site characteristics (e.g., aspect, elevation, soil type and substrate, proximity to water). Disturbances from herbivory, fire, forest management activities, recreation, and site conditions that include trails (number, size, and proximity to populations) and facilities, as well as



**Figure 11.** Photographs of six *Cyripedium montanum* monitoring plots at the Story location (WY-1) on the Tongue Ranger District, Bighorn National Forest. A-F correspond to plots C1, C2, TB1, TB2, TP1, TP2, respectively ([Table 3](#)). Thinned plots were located in an area that was lightly thinned and pruned. Photographs by Greg Karow, USDA Forest Service, used with permission.

evidence of current land use practices and management activities are important to document while monitoring occurrences (Elzinga et al. 1998).

For sites that are occupied by *Cyripedium montanum*, conducting habitat monitoring concurrently with population monitoring would be most convenient. The habitat and site information could be incorporated into a single field form that included entries for population monitoring. These data could be compared

with habitat identified as suitable but unoccupied by the orchid. Documenting habitat conditions that may change or are affected by disturbance is most important in identifying if and how habitat alteration is affecting population dynamics. Identifying indicator species and recording major exotic species with invasive potential augments understanding habitat requirements and management needs. Monitoring for invasive exotic species will provide needed information to take proactive measures and to prevent spread.

Habitat monitoring of known occurrences will alert managers of new impacts such as weed infestations and damage from human disturbance and grazing. Changes in environmental variables might not cause observable demographic repercussions for several years, so resampling the chosen variables may help to identify underlying causes of population trends. Monitoring usually occurs only during the growing season but seasonal effects on habitat over a yearly cycle and climatic changes over multiple years are important to consider.

Elzinga et al. (1998) point out that habitat monitoring is usually better at identifying new impacts than at tracking change in existing impacts because of observer bias. For estimating weed infestation sizes, using broad size classes helps to reduce the effects of observer bias. To assess trampling impacts, using photographs of impacts to train field crews would increase consistency in rating impact severity. Estimating cover and/or abundance of associated species could permit the investigation of interspecific relationships through ordination or other statistical techniques. For ocular estimates of cover classes or canopy overstory, spatial areas should be small enough and cover classes should be broad enough not to exceed the estimate's level of accuracy; otherwise, inconsistency may crop up in repeated measures.

Understanding what environmental and biological factors are limiting to this species would aid in prioritizing management actions. Gathering data on slope, aspect, and edaphic characteristics (if possible) from the permanent plots described above would permit the canonical analysis of species-environment relationships. These data would facilitate hypothesis generation for further ecological studies of this species.

Environmental assessments prepared during project planning may require specific monitoring when rare and sensitive species are present in the treatment area. In a treatment area, implementation and effectiveness monitoring are special cases of monitoring that focus on the management treatment and its effects. They would determine if specific measures were taken to mitigate treatment effects on the population and habitat. Monitoring would also document whether the habitat and the occurrences at the site were left in a condition that would not be detrimental to the species. In order to determine what parameters should be examined, information derived from habitat monitoring would be valuable in guiding the preparation of the implementation and effectiveness monitoring plans.

### *Beneficial management actions*

To meet the requirements for monitoring and evaluation of management activities outlined in the Bighorn National Forest Management Plan, an annual monitoring and evaluation report was prepared and posted on the USFS website ([http://www.fs.fed.us/r2/bighorn/projects/monitoring/2004\\_monitor\\_rpt\\_final.pdf](http://www.fs.fed.us/r2/bighorn/projects/monitoring/2004_monitor_rpt_final.pdf)). Monitoring *Cypripedium montanum* was an action item in the plan. Monitoring has been carried out for WY-1 (**Table 1**) as prescribed by the Story Fuels Environmental Assessment (USDA Forest Service 2003d). This furnishes a documented basis for determining future management of this occurrence. However, it would benefit the conservation of all occurrences if monitoring were not triggered only when projects are planned.

Increasing awareness among USFS personnel and educating field staff in identifying the species and making habitat assessments would expedite species inventory. A network of informed observers would increase the probability of finding new occurrences and detecting adverse events on existing occurrences. A Rare Plant Field Guide was developed during FY 2004 and sent to all of the districts on the Bighorn National Forest; this internal document was designed for use by USFS staff in the field to identify sensitive species, species of local concern, and demand species found on the Bighorn National Forest. The manual includes illustrations of plants and habitat, physical descriptions, habitat descriptions, flowering/fruiting times, taxonomic guides, and known locations. In addition, to facilitate program development and tracking, a Forest Rare Plant Management Strategy was developed as a 5-year action plan for FY 2004 through FY 2008. The purpose of the strategy was to provide guidance and direction for field surveys and monitoring, information on rare plant management as well as basic information on TES, sensitive species, and species of local concern. Both documents are on file at the Bighorn National Forest headquarters, Sheridan, WY (Karow personal communication 2005).

A single crew member inventoried approximately 104,000 acres of project area in 2004. The survey areas were selected by reviewing known element occurrences for habitat, soils, elevations, and aspect data. New plant locations were confirmed by specimen collections authenticated by WYNDD botanists. These efforts extended the *Cypripedium montanum* population near Story, Wyoming upstream and downstream along South Piney Creek. A new population in the Little

Goose Creek drainage along the forest boundary was also documented. Another population of *C. montanum* was documented just outside the Bighorn National Forest boundary along Red Grade road (USDA Forest Service 2004). Although the inventory produced new information, it was confined to project areas on the forest, did not include lands outside the National Forest System, and was not focused on *C. montanum*. Therefore, it probably was not as effective as a comprehensive inventory for *C. montanum*.

Monitoring for the spread of the noxious weed leafy spurge resulted in its discovery at WY-1 (**Table 1**), where it was treated. According to the Story Fuels Environmental Assessment (USDA Forest Service 2003d), leafy spurge would continue to be monitored and spot treated if necessary to control the spread of this species and any other noxious weeds. Coordination with weed management specialists to obtain information on new occurrences of invasive exotics would shorten the time of detection and reduce potential threat to rare species' habitat.

#### Ex situ conservation

No seeds or genetic materials are currently in storage for *Cypripedium montanum* at the USDA Agricultural Research Service National Center for Genetic Resource Preservation (NCGRP; Ellis personal communication 2005). Nor does the National Collection of Endangered Plants have *C. montanum* in its collection (Center for Plant Conservation 2005). In Oregon, the Berry Botanic Garden is storing *C. montanum* seed; however, the seed has not been tested for viability. In general, long-term storage of *Cypripedium* seeds is a challenge because of their small size and the presence of at least one fungal symbiont. Evidence that dry dormant seed could withstand long-term storage and remain viable varies among orchid species (Arditti 1967). Some progress in developing ways to cryopreserve orchid seed without detriment to the viability of seed and fungal symbiont has been reported in Australia (Wood et al. 2000). Long-term cryo-storage of carefully targeted and collected seeds will be useful for gene conservation, and possibly, in the future, reintroductions. In addition, micropropagation of seeds that have been collected and stored in the short term may have potential for genetic research and gene conservation. The USDA CSREES Small Business Innovative Research (SBIR) grants program is funding research to develop a means for conserving genetic resources through controlled propagation of thousands of seeds using *in vitro* techniques (Smith and Smith 2004). Seed storage and micropropagation are two tools

that Region 2 currently does not have but could acquire for gene conservation. They are essential for managing the limited but important genetic resources available in Region 2 for this species.

### **Information Needs**

#### Population issues

Knowledge of factors that affect *Cypripedium montanum* distribution is a key element to conserving the species because populations of *C. montanum* in Region 2 are typically small and scattered, making them vulnerable to extirpation. Maintaining distribution of the species across the landscape sufficient to avoid significant discontinuities among populations is a key factor in providing for persistence. Although the known distribution of *C. montanum* is localized in Region 2, it may be underrepresented because potential habitats have not been thoroughly surveyed. An accurate representation of the distribution of a species on the edge of its natural range is important in determining trends for the species as a whole. Because *C. montanum* populations in Region 2 are isolated and peripheral, they may be more genetically divergent (Lesica and Allendorf 1995). In order to determine the relation between the populations' spatial distribution and the species' gene distribution, a genetic analysis should include regional sampling of the nearest populations in adjacent states and, ideally, across the species' full range.

A comprehensive inventory of *Cypripedium montanum*, adequately documented in a database, is needed within Region 2. Attempts to relocate historic occurrences are warranted because they were documented beyond the present range of *C. montanum* in Region 2, indicating that more suitable habitat exists. Historic occurrences also merit investigation to determine if changes in habitat could be associated with occurrence loss. Much potential habitat within the historic and current range boundaries of *C. montanum* in Region 2 remains to be systematically evaluated. Identifying habitat and mapping occurrences nearest those in Region 2, such as in the Yellowstone River Valley approximately 100 air miles northwest of the closest occurrence in Wyoming, will define more precisely the historic and current distribution of the Region 2 occurrences. It will also clarify the degree of spatial discontinuity in relation to closest occurrences outside the region.

An analytical approach to evaluating diverse *Cypripedium montanum* habitats is also needed. Maps

of potential habitats could be based on information from known occurrences and include habitats that match those in which *C. montanum* occur. In this way, core areas of distribution and key habitat areas could be defined. More information is needed to identify, train staff, and search for potentially suitable habitat. This would involve cooperation across ownerships where *C. montanum* is known to occur.

Although the reproductive ecology, mycorrhizal relationships, and *in vitro* seedling establishment of *Cypripedium montanum* are being studied, community ecology and the effects of environmental or climatic variation have not been investigated. This lack of information hampers assessment of the effects of various management options during project planning. The longevity of viable seed in a natural seed bank is unknown for *C. montanum*. Persistence of a seed bank depends on the species accumulating and maintaining more seed in the seed bank than the parent plant's annual seed production. This does not take into account seed blowing in from nearby plants and fluctuations in the amount of seed produced each year. Complicating the ability to assess whether *C. montanum* seeds exist in a seed bank is the seed's almost microscopic size, light weight, and dispersal by wind and water (Arditti 1967).

Very little is known about population trends of *Cypripedium montanum*. Baseline population size data are difficult to acquire unless, at a minimum, an annual census of each population is taken for a number of years. Historic records as well as known occurrences are few in number, but with greater coverage by surveys and species specific inventories, more occurrences might be documented. Monitoring would follow the temporal and spatial changes in populations, but at present (except WY-1 in [Table 1](#)), there are no monitoring data with which to determine population trend. Basic life history parameters need to be determined from which the viability of occurrences can be inferred.

The persistence and population stability of *Cypripedium montanum* require that habitat be managed so that connectivity between populations is maintained. There appears to be more unoccupied habitat suitable to this species than occupied (Karrow personal communication 2005). Information that would be generated from autecological studies would aid in developing more precise criteria for determining appropriate habitat. With a more precise definition of suitable habitat, interpretation of unoccupied habitat would be more accurate. Information on soil microbiology might yield valuable insights into the ecological requirements of *C. montanum*, which would

facilitate effective habitat monitoring and conservation stewardship of this species. Evaluations of soil, moisture, and light parameters correlated to specific environmental conditions that limit *C. montanum* growth and life cycle would help in modeling the species' distribution. Seed provenance (a source of seed that show similar genetic adaptability) would be an important aspect of characterizing the genetic structure of the Region 2 populations particularly because of their isolation and location on the periphery of the species range. It is important that genetics research also address provenance and distribution of the fungal symbionts and their associates because their genetic structure and genetic differentiation among populations are not understood but could profoundly affect seed transfer (Krauss et al. 2005).

The role of herbivory in the ecology of *Cypripedium montanum* is not understood. Current data are inadequate for forming conclusions as to whether insect predation or herbivory has a significant effect on biomass, reproductive success, or population viability. Climatic changes could create conditions for invasions of competitive plants and predatory insects. Although attention is beginning to focus on this issue with studies of how climate affects beneficial and predatory insects in association with plant species (Miller-Rushing and Primack 2004), little is currently known. Historical use of land for grazing has a widespread effect on plant communities and habitat, but its immediate consequences for *C. montanum* are not known. Cattle are present in allotments in proximity to *C. montanum*, a situation that increases the need for land managers to have better information on the effects of grazing and trampling on habitat and soil quality, introduction of undesirable plant species, and on pollinators and mycorrhizae associated with *C. montanum*.

*Cypripedium montanum* populations have not been evaluated to determine whether metapopulation structure and dynamics are critical factors in its long-term persistence at local or regional scales. Migration, extinction, and colonization rates of *C. montanum* are unknown; however, because of the small number of populations in Region 2, population viability analysis using demographic and other pertinent data sampled from all populations within the region would give a reasonably reliable estimate of species status (Harrison and Ray 2002). Metapopulation dynamics are difficult to ascertain, and most have been conducted on animal species. Few studies have been conducted on plant species because most do not have the kind of long-distance dispersal mechanisms that allow populations to vary (i.e., become extinct, migrate, and colonize).

Although *C. montanum* is distributed across a fragmented landscape, trying to assess metapopulation dynamics may not be as useful or relevant as understanding population dynamics and viability, and protecting suitable habitat (Elzinga et al. 1998).

The population structure and demography of *Cypripedium montanum* occurrences have not been characterized; consequently, no population data have been collected. Little information on growth, survival, and reproduction rates has been collected in Region 2. Knowledge of species distribution is incomplete; therefore, demographic information needs to be gathered before local and range-wide persistence can be assessed with demographic modeling techniques. Short-term demographic studies, particularly for a species with a complex life cycle, result in misleading information; therefore, an approach that incorporates complementary information, such as historical data and experimental manipulations, should be included whenever possible (Lindborg and Ehrlén 2002).

#### Restoration methods

Restoration of sensitive or rare orchid species, whether through *in situ* or *ex situ* conservation, is controversial and debated in the literature (IUCN/SSC 1996, Koopowitz 2001). Much habitat is protected in reserves and protected areas, but these may be insufficient in number and distribution to restore the historic range and abundance of a species. To re-establish this species' historic distribution, areas identified as having potential for becoming a reserve may need to be restored. Restoration of such areas could be as simple as removing grazing livestock and controlling invasive exotics; a study to test this hypothesis is needed to determine if removing livestock affects population viability and lessens extirpation risk. The IUCN/SSC Orchid Specialist Group (1996) recommended that protected areas include small as well as large habitat patches and once established, should be monitored and managed.

More information is needed to guide restoration on private lands. Small patches of undisturbed habitat in places commonly disregarded for conservation, particularly on private land, can play an important role if they serve to protect endemism (IUCN/SSC 1996). Restoring habitat through controlled burning or pruning of overtopping canopy may be an effective method to increase a dwindling population, if the cause has been determined to be environmental (canopy lowers soil temperature and reduces light to detrimental levels). This has been done on an experimental basis at GROWISER

in eastern Oregon, where a combination of propagating orchids from collected seed and pruning and thinning to create habitat openings is attempting to increase the abundance of *Cypripedium montanum* (Huber 2002). Reintroductions require more information about seed management and handling and the proper timing, soil preparation, and techniques for sowing.

Whitlow (1990) suggested that maintaining selected plants in botanical gardens dedicated to native species preservation through propagation, distribution, and hybrid production, minimizes the need for collecting wild material. However, *ex situ* propagation of *Cypripedium montanum* from seed is still experimental and in trial stages (Smith and Smith 2004). Even if plants are successfully propagated in a greenhouse environment, there is little evidence that re-introducing the cultivated plants into a natural or restored setting will ensure their establishment. Information on seed provenance that would be critical to this approach (Krauss et al. 2005) is currently lacking for *C. montanum* and for orchids in general.

#### Research priorities for USDA Forest Service Region 2

Criteria for prioritizing research should be based on filling knowledge gaps in understanding the biological and ecological factors that limit population growth and persistence, and habitat conditions most directly related to species vulnerability. Research should also provide the ability to accurately project future scenarios for species persistence. Research might address, for example, the adaptive limitations of *Cypripedium montanum* (e.g., dependency on specific mycorrhizal fungi) and identify how that limitation affects population viability. Research that addresses increasing understanding of the species' life cycle, genetic structure, and essential elements of its habitat will help in not only maintaining the species but also provide capability to predict disturbance responses. Spatial analysis of distribution and habitat that include historic climatic and large disturbance effects also would aid in projecting future distribution and abundance of the species under different long-range climate scenarios.

The response of *Cypripedium montanum* to human impacts and disturbance has not been studied in Region 2, with the exception of demographic monitoring at the Story site (WY-1 in **Table 1**). Gaining practical knowledge of how best to manage *C. montanum* populations is of considerable importance, given the rapid change in land use patterns, increasing

recreational use, and increasing human population density of the Front Range. Relevant research topics for *C. montanum* might include the following:

- ❖ effects of disturbance on temporal and spatial distribution, abundance, and available habitat
- ❖ habitat and environmental factors associated with seed germination and seedling establishment
- ❖ influence of fire (wildfire and controlled burns) disturbance and/or vegetational changes on habitat and demography
- ❖ habitat requirements of pollinators; environmental and ecological factors that affect pollination success
- ❖ factors that influence recruitment and seedling mortality
- ❖ factors that affect fungal symbionts' association with *C. montanum*
- ❖ genetic provenances and genetic structure

- ❖ *in situ* techniques for increasing small populations.

#### Additional research and data resources

Research on the pollination and reproductive biology, mycorrhizal ecology, and demography of *Cypripedium montanum* is in progress. Funded research related to restoring the species through *in vitro* propagation is clarifying that part of the life cycle related to seed germination, protocorm, and the developing seedling during its mycotrophic phase in its natural setting (Smith and Smith 2004). Information from these studies can improve understanding of orchid reproduction and the ecological requirements of pollinators and mycorrhizae. The pollination ecology study will document the most common pollinators and their behavior. Information on the breeding system of *C. montanum* obtained from Peter Bernhardt and presented in this document is preliminary and will be published in a refereed publication. Mycorrhizal fungi studies (Luoma personal communication 2005) should characterize the fungal taxa and plant-fungi relations of *C. montanum* during different phases of the orchid's life cycle, providing information that may identify phases that are most vulnerable.

## DEFINITIONS

**Autotroph** – organism capable of converting carbon dioxide into metabolic carbon for its own use (phototroph, through photosynthesis, chemotroph, through chemical metabolism).

**Capsule** – dry, dehiscent fruit.

**Damping off** – sudden plant death in the seedling stage due to the attack of pathogenic fungi; the extent of damage is related to the fungus, soil moisture, and temperature.

**Effectiveness monitoring** – monitoring that determines if management activities are effective in producing desired conditions.

**Fusiform** – elongated and tapered at each end like a football.

**Geophyte** – a perennial plant having perennating buds located below soil surface, for example, on a rhizome.

**Geotropic** – oriented in response to gravity.

**Hybrid swamping** – the concept that a common species can cause the extinction of a rare species by hybridizing with it and “swamping” the unique genetic profile of the rare species.

**Implementation Monitoring** – monitoring that determines if management activities are designed and carried out in compliance with forest plan direction and management requirements.

**Insolation** – reception of solar radiation.

**Labellum** – the pouch or lip of the orchid flower derived from a modified petal.

**Mycorrhizae** – symbiotic relations of plant roots and fungi.

**Mycotrophic** – living symbiotically with a fungus and nutritionally dependent on fungus.

**Perennating bud** – the bud of a perennial plant that overwinters in a dormant state and sprouts the following spring.

**Perennial** – a plant that normally lives for more than two seasons.

**Phenotypic plasticity** – the capacity for marked variation in the morphology of an organism as a result of environmental influences.

**Protocorm** – a pre-rhizoid structure that develops from the germinating embryo putatively with a fungal symbiont and from which roots and shoot eventually develop.

**Pubescent** – covered with hair.

**Ramet** – a member of a clone such as rooted cuttings or rhizomatous shoots that are identical genetically but can live independently.

**Rhizomatous** – possessing underground stems that often produce roots and shoots.

**Self-sustaining populations** – populations that are sufficiently abundant, interacting, and well distributed in the plan area, within the bounds of their life history and distribution of the species and the capability of the landscape to provide for their long-term persistence, resilience, and adaptability over multiple generations.

**Sensitive species** – those species for which population viability is a concern and identified by a regional forester as requiring special management as directed in FSM2670.

**Seral** – pertaining to an early stage of succession.

**Staminode** – a sterile stamen and in *C. montanum* a structure that partially covers the pouch opening.

**Symbiont** – an organism that interacts in a relation with another organism – maybe, but not always, to their mutual benefit.

**Sympatric** – species or populations that inhabit the same or overlapping geographic areas.

**Sympodial bud** – a lateral bud that forms just behind the tip of a composite axis, elongating the axis.

**Synsepal** – two fused or partially fused lateral sepals found in *Cypripedium* species.

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